ECHNOLOGY DEPT:
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ONE SHILLING & SIXPENCE

Plastics

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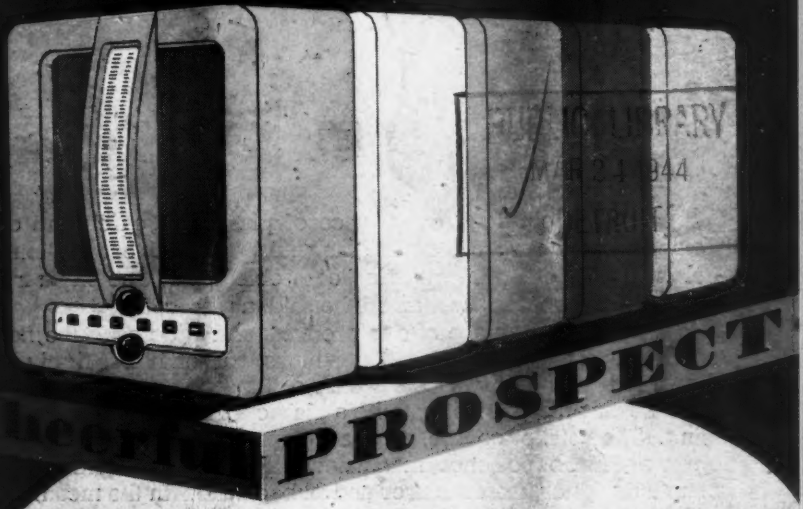

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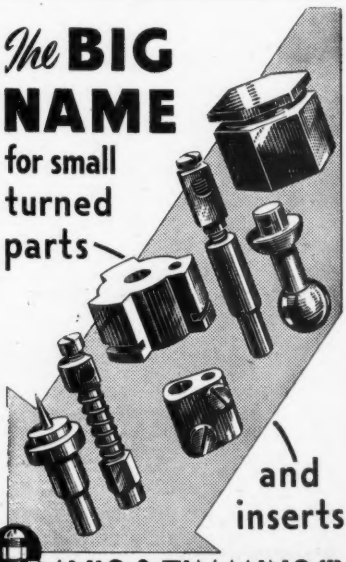

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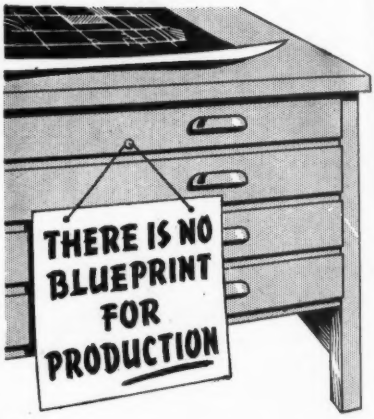

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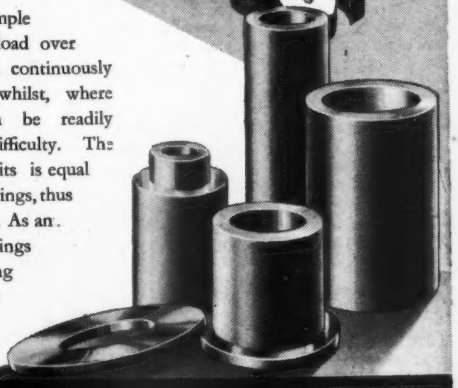

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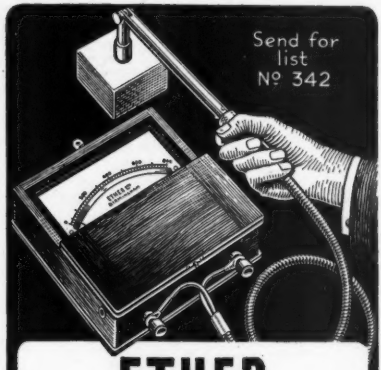

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C. R. Casson 2

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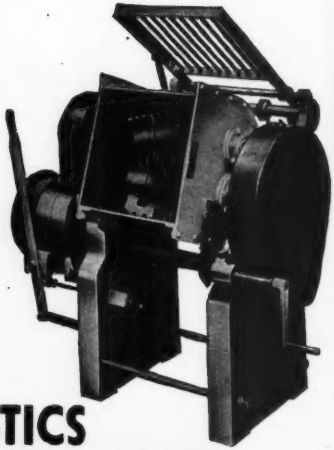

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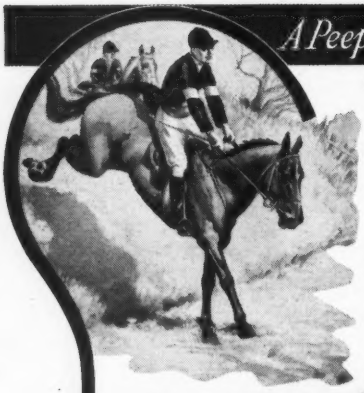

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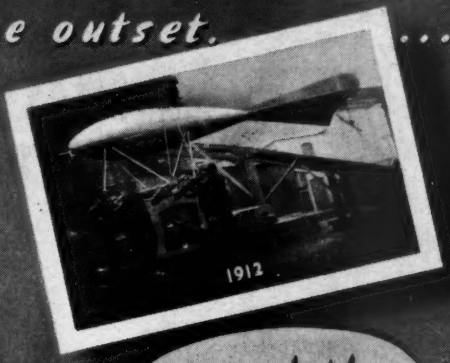

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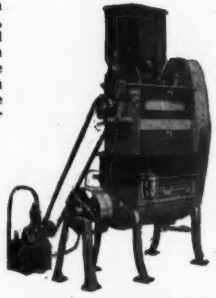

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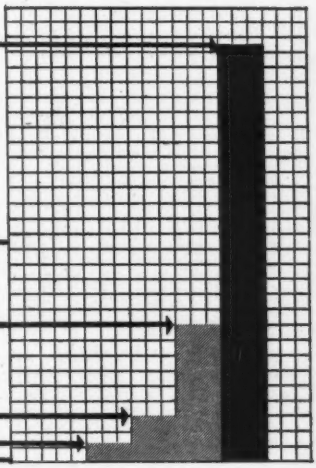

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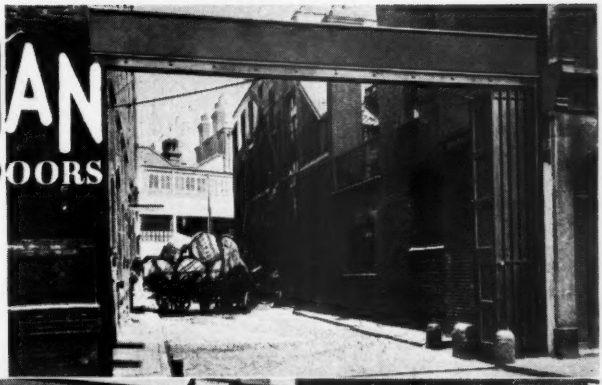

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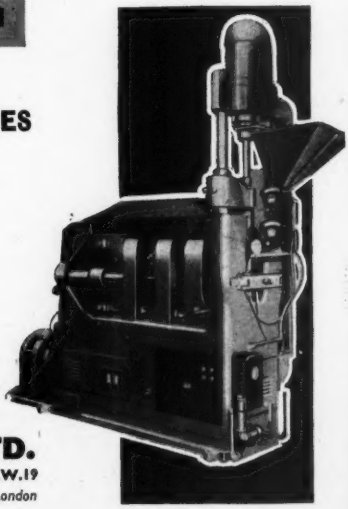

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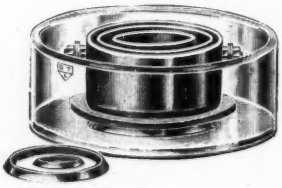

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Pioneers in the Plastics World

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Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

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Editor - - M. D. CURWEN, B.Sc., A.I.C.
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NOTICES

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EDITORIALS

Leo Baekeland

LEO HENDRIK BAEKELAND is dead and with his death there passes a man who, perhaps more than any other in the world, was responsible for the growth of the synthetic resin production and moulding industries as they exist to-day. He was born in Ghent, Belgium, in 1863, but at the age of 26 went to America. He first attracted world-wide scientific attention through his work on photography, inventing the well-known Velox gaslight photographic printing process, and, later, devoted his wide chemical knowledge to the examination of resin formation of phenols. Other workers for many years past had noted the curious reactions between carbolic acid and formaldehyde, but it was Baekeland who discovered, between 1907 and 1909, the exact conditions by which the reactions could be controlled and the means, which could be translated into works practice, to obtain by further heating at high temperatures, an insoluble and infusible material.

To-day the word Bakelite is almost synonymous, certainly to the general public, with any phenolic resin, so wide and great are these plastics. The uses have grown far beyond the early conceptions of Baekeland, but even all new ones are, in a sense, reflections of his genius. The Bakelite Corpn. of U.S.A. grew great, and with its links in other countries effected an industrial revolution.

He was the recipient of academic awards throughout the world, among them being the British Messel Medal of the Society of Chemical Industry and the honorary degree of Doctor of Laws by the University of Edinburgh.

From the country of his adoption, which he enriched so materially and which is always so ready to recognize and reward industrial genius and research, he received praise in full measure, one of the interesting tributes being the inclusion of his portrait as an eminent man of science in the beautiful mural painted in New York by the artist, David Hutchison.

Identifying Plastics

THERE is, without doubt, a growing need for the simple and rapid identification of plastics. This need has been indicated by a wide variety of users, chemists, physicists, engineers, and also by the non-technical who come into contact with plastics in ways which range from buying to storage. What is quite disconcerting is that the problem is becoming more puzzling and more difficult very rapidly.

Unfortunately, what may be considered "simple and rapid" by the chemist is not necessarily so to the non-technical man or to the engineer, who would like methods quite divorced from chemical ones, and would prefer those devoid of mental gymnastics and akin to the simple visual identifications employed in engineering shops where steel is so different from copper, brass or aluminium in appearance or weight. Even in engineering stores, with the enormous growth in the number of new alloys and, indeed, metals, identification is no longer simple, and storage has become a full-time job for a special department.

The visual distinction between some plastics is easy, but in many cases it is difficult. It would tax the ingenuity and experience of most experts to distinguish between many of the transparent plastics, and especially between many opaque mouldings; the difficulty will grow with

time. It may be that for most engineering concerns the difficulties are exaggerated, for doubtless the number of plastics employed will probably be limited. We foresee, however, a headaching time in store for those concerns akin to Hobbies, Ltd., which may, after the war, wish to help the growing demand by an army of amateurs for a bewildering array of rods, tubes, sheets, and even, perhaps, moulding powders and cements made from a dozen or more different plastics. There's a very tangled skein to unravel.

Apart from this branch of industry, there is a large number of technologists, especially in the radio and allied electrical industries, who wish to distinguish between various plastics for reasons which are technical or generally investigational of plastics whose character is not disclosed. For this type of worker, is a simple and rapid technique for identification possible?

In the early days (and we speak of only five to ten years ago!), when the number of varieties was few, it was relatively easy to make distinctions between them all. There was no need for any true chemical analysis and there grew up the use of an elementary technique of burning the plastic in a flame and of using one's nose. It is interesting to note that such a method appeared in printed form in " Synthetic Resins and Allied Plastics," by R. S. Morrell and others.

Thus a means of distinction between celluloid and cellulose acetate lay in the difference in rate of burning and in the fact that the latter, on burning, gives off an odour of acetic acid. Phenolic resins give off carbolic acid or formaldehyde odours if there are no red herrings due to wood flour. Casein reminds us of the blacksmith's smithy or of burning hair, and urea resins can be identified by the ammoniacal smell.

Thus far it was quite simple. When, say, polyvinyl chloride came on the scene, a new smell on heating, that of hydrochloric acid, entered the arena. Also a simple test, that of heated copper wire, which gives a green colour to the flame with a chlorine-containing material, was simple enough even for the non-technical. Methyl methacrylate and other similar plastics, polystyrene, polythene, the Formvars, Gelvas, ethyl and benzyl celluloses and cellulose aceto-butyrate, however, began the real complications with odours that sometimes did and sometimes did not remind us of the myriad scents of Araby. We have not attempted to burn the synthetic rubbers, but, presumably, they are not pleasant. Thiokols have a delightful odour of their own which need no adventitious aid for their identification. Nylon, strangely enough, smells on burning, not of protein but of celery!

Even the simple heated copper wire test described above is now virtually useless since both neoprene and Saran would, presumably, give a green flame.

To complicate the matter still more, the number of plasticizers (the percentages used are often very high) is increasing steadily, and we can readily imagine one plastic made by different makers to behave quite differently in odoriferous effects because of this.

There are even very simple chemical tests for nitrogen and sulphur which can be carried out rapidly by non-chemical persons with a few chemicals, but how far would this carry us as time goes on?

All this does not seem very helpful, but, after all, we are dealing with complicated chemical materials, and it may be the wisest plan to resort to the help of the plastics or chemical consultant who is well able and organized to do the job.

Plastics at War

BX Plastics, Ltd., with the co-operation of the Ministry of Supply, is presenting " Plastics at War," an exhibition illustrating the part played by plastics in modern warfare. The exhibits have been loaned by the Admiralty, War Office, Air Ministry and the Ministry of Aircraft Production. It will be held at the Village Hall, Brantham, from March 8 to 22, 1944, and the proceeds will go to the British Red Cross Society. Commander A. B. Campbell will open the exhibition on March 8 at 2.30 p.m.

The Welding of Thermoplastic Materials by Means of Radio Frequency Currents

By H. P. Zade (Arc Manufacturing Co., Ltd.)

As a complementary note to Mr. Haim's article on heat-welding in the January issue of "Plastics," the present author describes radio frequency welding from both historical and practical points of view. He includes, what has been lacking in general descriptions of the subject, a very complete list of references to the scientific and patent literature

IN a recent paper[1] a number of processes used for the jointing and welding of thermoplastics have been discussed. The radio frequency welding method was not included. Fundamentally this type of welding process is based on heating and consolidating the material under pressure. It might be of interest, therefore, to discuss the history of radio frequency heating of thermoplastics before the actual welding process is described.

Historical and Theoretical Aspects of Radio Frequency Heating

In a very early patent (B.P. 217,869) a method for the application of high frequency to the heating and drying of paper cable insulation is described. Dewalt[2] discusses the merits of radio frequency heating for medical purposes and refers to the early work of Whitney (B.P. 310,925). The last-mentioned patent deals with the heating of bodies in high frequency fields, and valve oscillators are used for the purpose. Lay[3] presents the point of view of the biologist, dealing with the application of high frequency currents in medicine and surgery. An extensive review of all electro-thermal aspects of high frequency heating is given by Brajnikoff[4], while industrial applications are mentioned by several authors.[5, 6, 7] One of the most recent publications is provided by the "Symposium of the Society of Plastics Engineers"[8] where a great wealth of information on all points of high frequency heating is given.

The heating of imperfect dielectric materials, and most plastics definitely come under this heading, is based on their dielectric constant and loss factor. The differences in heating of individual materials are, therefore, closely related to these two physical properties. In a very comprehensive article, Yager[9] includes a large number of graphs which correlate dielectric constant and loss factor with frequency and temperature. From these graphs it is evident that there are preferred frequencies which will yield the maximum heating effect and also that while the material heats up, alterations in the power consumption independent of the applied radio frequency voltage occur.

In this connection it should be mentioned that a great deal of research has been carried out with regard to measurement of dielectric constant and determination of loss factors of plastics by members of the National Physical Laboratory[10, 11] and other workers.[12, 13]

Processes Closely Related to Radio Frequency Welding

Before going into the question of the welding proper, it may be of interest to mention a few other applications of radio frequency which are closely related to welding. We can distinguish the following fields of application:

(a) Pre-heating of parts for moulding purposes.

(b) Manufacture of resin-bonded plywood and similar articles.

(c) Vulcanization of rubber.

(a) In the field of pre-heating resin powders for moulding purposes a great deal has been published, particularly in the U.S.A., and only a few papers shall be mentioned here.[14, 15, 16, 17] The article by Meharg[14] describes in detail the so-called "Heatronic Moulding" process. This process has been patented in the U.S.A., but with the unusual clause that the patent is open to anyone who wants to use it.

(b) A large amount of information is available on the manufacture of resin-bonded laminates.[18, 19, 20, 21, 22, 23, 24, 25, 26] In the field of heating and bonding of plywood or similar laminated material using thermoplastic or thermosetting glue, particular prominence has been given lately to the manufacture of aircraft parts.[20, 22, 26] The jointing of plywood veneers can almost be called a welding process, as the definition of the welding of plastics at the time of writing has not been settled. For a plastic bond no definite melting of the boundary of the work pieces takes place as in the case of metals.

(c) Vulcanization of rubber: Leduc[27, 28, 29, 30, 31] describes the application of radio frequency methods to the vulcanization of rubber. It is interesting in this connection to mention that in two early British Patents (472,764 and 495,520) Leduc and Dufour described the vulcanization and the joining of rubber to metal by means of induction heating. Probably the radio frequency method is a development of this earlier work.

Radio Frequency Welding of Plastics, Stationary Methods

Discussing the actual welding of plastics a distinction can be made between the "stationary" welding methods, such as spot, butt and lap welding, and "continuous" methods, such as seam welding by means of rotating rollers. Two papers deal with spot-welding methods.[32, 33] In a paper entitled "Spot Welding with Glue,"[32] the joining of spars of wood by means of a cold-setting type of resin glue is described. The glue is polymerized in places 13 ins. apart by means of a high frequency spot-welding tool. The so-called "cycle-weld" process[33] has been developed by the Chrysler Corporation of America. This method makes use of a special thermoplastic cement and, among other sources of heat, employs radio frequency to bond plywood under hydraulic or mechanical pressure.

Control of Electrostatic Fields

In the case of butt, lap and seam welding, particularly of comparatively "heavy" sections (thicker than $\frac{1}{4}$ in.), it has been found that the shape of the electric field and of the electrodes producing this field has a great influence on the heating process. Apart from the factors which are fixed by the material to be welded, i.e., dielectric loss factor and dielectric constant, the main determining agent for the generation of heat is the field strength. Provided the frequency is kept constant and no appreciable differences in the dielectric loss and dielectric constant occur due to temperature change, the heating effect increases in proportion to the square of the field strength. The field strength is determined by the geometrical shape of the electrodes used for the welding process and, naturally, by the value of the applied voltage. The problem in connection with high frequency welding is that of exploring the distribution of electric potentials for any given assembly of electrodes. Obviously, it is not very easy to explore the actual radio frequency field, although such a method has been described for a frequency of 3 megacycles.[34] A simplified method has been developed and a special apparatus was designed[35] for a convenient step-by-step plotting of the potential distribution in a scale model of the set-up to be used for high frequency welding.

This method is based on the well-known electrolytic bridge which is used, for instance, in the measurement of field distribution in high-tension cables. The main problem to be solved, however, is that of making an electrolytic replica of an arrangement representative of more than one dielectric. The solution of this

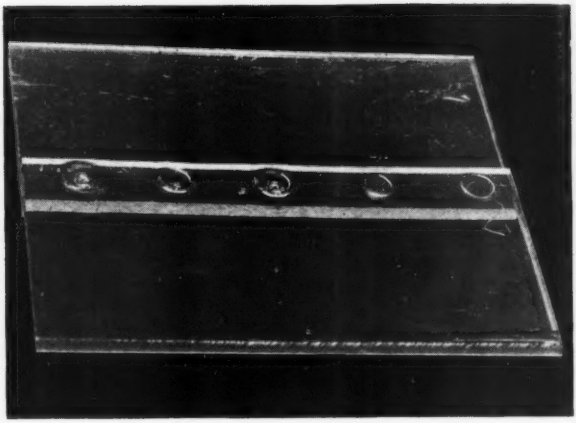

Fig. 1.—Correct and faulty spot welding of two thermoplastic sheets. Note gas bubbles on three of the welds.

problem, described in B.P. 555196, is the following: Metal electrodes are represented by metal electrodes, while dielectrics of different dielectric constants, for instance "Air" and "Perspex" are represented by gels of different electrolytic conductivities. In this manner it is possible to reproduce any type of arrangement of welding electrodes where air gaps or materials of high dielectric constant are used in the vicinity of the weld. Figs. 1-5 show various types of actual welds, all of them made in Perspex (methyl-methacrylate).

Fig. 1 represents spot welds of two sheets $\frac{1}{4}$ in. added thickness. It will be seen that three of the welds show a slight development of gas bubbles which is due to overheating. The need for accurate time and current control is evident and in this respect good use can be made of the experience gained in the resistance welding of metals. Fig. 2 shows a lap weld consisting of six layers of $\frac{1}{4}$-in. Perspex sheet welded into a solid block by means of radio frequency and pressure. In this case a plastic cement was used between the individual layers, the high frequency current effecting polymerization of the adhesive and bonding to the material. Fig. 3 shows a plain butt weld of $\frac{3}{8}$-in. Perspex sheet, the left-hand picture illustrating the weld as it left the pressure jig, while in the right-hand view the excess material has been machined off and the sample has been polished afterwards. Fig. 4 was a special problem of welding preformed sheets of Perspex in such a manner that a small space was left between the sheets. This space is intended for the circulation of air and the weld itself has to be completely airtight. Fig. 5 illustrates the danger of overheating materials due to high electric field concentrations in certain spots. It can be clearly seen that in the centre of the welded Perspex block, gas bubbles have been produced probably by the

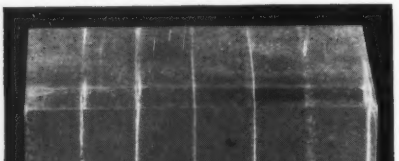

Fig. 2.—Lap weld of six layers of Perspex, using polymerizable plastic cement.

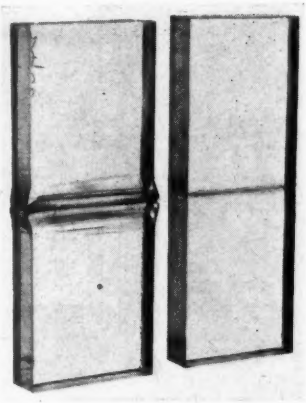

Fig. 3.—Butt welds of Perspex before and after machining and polishing.

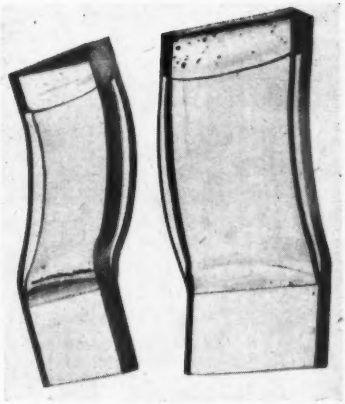

Fig. 4.—Welding of preformed Perspex.

expansion of the plasticizer, which, however, did not succeed in bursting the material. This latter picture illustrates the point that care should be taken to "design" the fields and arrangements of electrodes in such a way that overheating is prevented.

As a matter of interest it should be mentioned that this property of generating "bubbles" in plastics by means of high frequency currents is made use of in the manufacture of sorbo rubber (B.P. 518,517).

The illustrations 6-9 show some of the results obtained with the help of the authors "field plotter" method. Fig. 6 is the case of a plain butt weld, using two cylindrical electrodes which are off-set. The curved lines represent equi-potential lines, i.e., they connect all points of the same relative potential in the plane of exploration. The potential for each line is indicated by a figure. Calling the potential of one electrode 0 per cent. and that of the other one 100 per cent. for one infinitely short period of time, the distribution of the field is represented by the distribution of these equi-potential lines. Field strength is defined as the potential difference between two neighbouring lines divided by the shortest distance between the two lines. The deflection of these lines where they enter the plastic material is due to the difference between the dielectric constants of air and plastic. A concentration of the lines near the electrode indicates that the field strength of such points is higher than elsewhere. Overheating is, therefore, to be expected at these points of concentration before the surfaces of the pieces to be joined reach welding temperature. Fig. 7 illustrates a case where two pairs of electrodes are

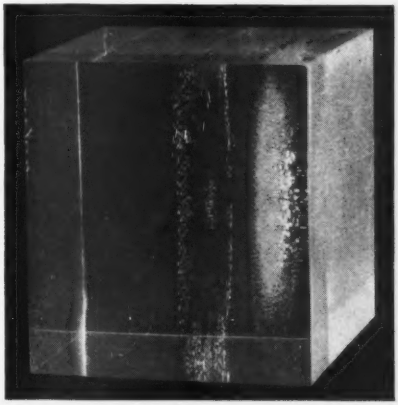

Fig. 5.—Faulty welds due to overheating.

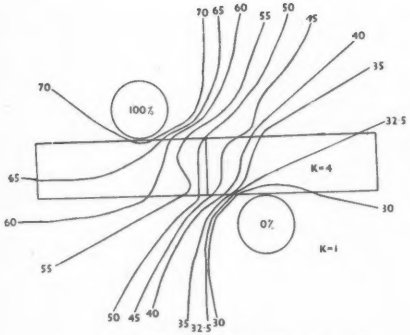

Fig. 6.—Plotting of iso-potentials for simple butt weld.

embedded in a material with the same dielectric constant as the blocks to be welded. The embedding material is Mycalex and its loss factor is very much lower than that of Perspex. No appreciable heat losses are to be expected in the Mycalex. The run of the equi-potential lines provides a good picture of what is going to happen with regard to heating in the various parts of the set-up. Fig. 8 shows the field distribution in the case of two pairs of flat electrodes,

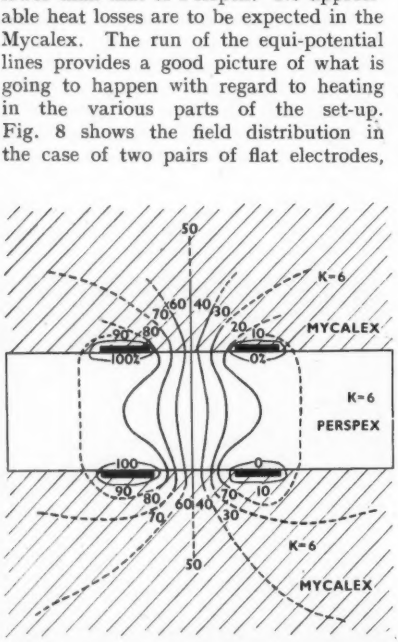

Fig. 7.—Equi-potential lines for electrodes embedded in Mycalex, employed for welding of Perspex.

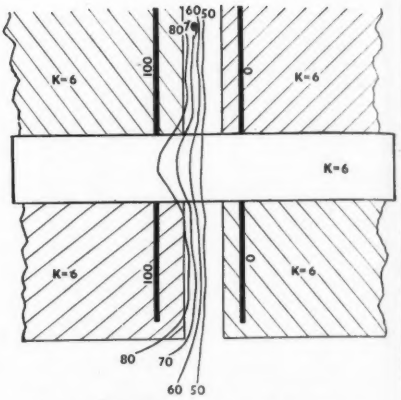

Fig. 8.—Distribution of field in case of electrodes at right angles to plastic.

located at right angles to the material to be welded. In this case only equi-potential lines from 50 to 80 per cent. are shown. Fig. 9 is a representation of a three-electrode arrangement, two of the electrodes being embedded in a low-loss material, while an additional air gap in the vicinity of the joint has the effect of drawing equi-potential lines away from certain corners.

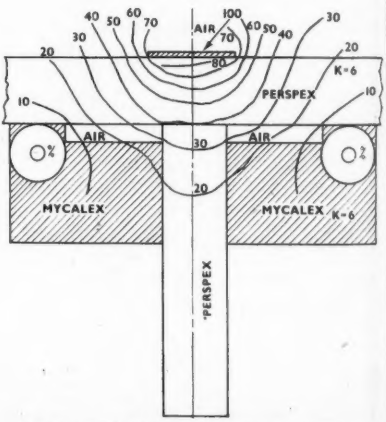

Fig. 9.—Field for three-electrode arrangement, two of which are embedded in Mycalex.

Radio Frequency Welding of Plastics, Continuous Methods

Methods of welding discussed so far refer to material of substantial thickness and the welds are produced by employing stationary jigs, in other words, discontinuous methods.

The earliest attempts to weld plastics in this country date back as far as the beginning of 1940. The high frequency continuous seam welder is one of the products of this development. In its later form a standard sewing machine was modified for the purpose. This seam welder contains a small oscillator feeding radio frequency into two counter-rotating rollers. The rollers are positively driven from a geared motor unit and the material to be welded is passed between the rollers. The top roller is spring loaded and pressure is consequently exerted on the material while it passes through. Thin sheets of resin or resin-impregnated fabric can be welded in this manner and airtight seams are obtained. The operation of the machine closely resembles the operation of the ordinary household sewing machine and girls can be easily trained to use it. There is no danger of shock by high frequency, as the top roller is earth connected and the bottom roller is inaccessible to the operator. Brown[36] mentions a similar seam-welding process, although he does not describe it in detail.

At approximately the same time the Radio Corporation of America has developed a high frequency seam welder which is called a "Radio Sewing Machine." The operation of this machine seems to be on similar lines.[37, 37a, 38, 39]

One word of warning should be given to prospective users of high frequency welders. Some thermoplastic materials, e.g., polystyrene and polyethylene, possess a very low loss factor and will not develop sufficient heat for welding if commercial radio frequencies are used. It is, therefore, not to be expected that in spite of the comparatively low fusion point of polyethylene good welds can be produced even from thin sheets, unless the frequency is increased to an extent which at the moment does not seem to be practicable.

It should be mentioned that it is necessary to screen such high frequency welding machines, as otherwise there is the danger of radiation and interference with short-wave wireless communications. The General Post Office has issued regulations dealing with the screening of high frequency plant and a permit for the use of such equipment is granted by them provided the plant conforms with the official regulations. The conditions imposed for screening do not involve much expense; ordinary wire netting of sufficiently narrow mesh can be used for the purpose.

Radio Frequency Welding of Glass

A very interesting application of radio frequency is the welding and repairing of glass.[40, 41] In the case of the welding of glass either one or both electrodes of the radio frequency circuit consist of small pilot flames of coal gas. These flames are too small to have any heating effect, but ionize the surrounding area, thus rendering it conductive for the high frequency current. Guyer[40] claims that chemical glassware can be repaired in this manner, and normally difficult operations such as the welding of flat bottoms to tubes can be carried out easily. The main advantage of this method consists of an exact control of the glass temperature and a sharp definition of the heating zone.

Radio Frequency Power Supply

This article would not be complete without mentioning the problem of radio frequency power supply.[42, 43] Among other things the choice of frequency is of great importance for the design of oscillators. At the moment of writing no single standard radio frequency can be stated which would satisfy all requirements. The necessity to control the RF power in the case of heating or welding of plastics is obvious. Unfortunately, radio frequency energy does not lend itself easily to measurement by usual methods. In this connection the work of Mittelmann

and Kobak[44] should be mentioned, who give data on energy obtained in "patient" circuits in the case of medical diathermy. Brown, Epstein and Peterson[45] have developed a direct-reading watt meter for radio frequency which can be used between .2 and 2 megacycles. A very interesting method of measuring not only the intensity, but also the direction of the field strength in actual radio frequency fields, was evolved by Lion,[46] who uses a photo-electric method to determine the glow excitation of an enclosed gas volume at low pressure due to high frequency potential differences. By refraining from the insertion of metallic conductors distortion of the field is avoided and a sensitivity of 10 volts/cm. at 50 megacycles is claimed for the method. Another way of measuring field strength is the use of a valve voltmeter operated from a small diode, the anode voltage of which is supplied by one terminal of the work circuit.

Conclusions

There seem to be quite definite fields of application for both welding methods (hot gas and high frequency) and it does not seem likely that there will be fierce competition between the two fundamental methods.

It is certain, however, that large-scale development of high frequency welding is to be expected in the near future, as soon as powerful high frequency plant will be readily available on the market.

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NOTE.—The following list of patents relating to high frequency heating and allied processes has been compiled with the help of I.C.I. (Plastics) Ltd., Welwyn Garden City, and Rediffusion Ltd., London, to whom the author would like to express his thanks for their valuable co-operation.

Patent Literature.—British.

No.	Inventor	Subject matter
217,869	Metrovick communicated by Westinghouse	H.F. drying of paper, electrostatic and electromagnetic. Roller system. Frequency: 1 megacycle
310,925	Whitney BTH	Electrostatic heating of bodies in H.F. field
417,501	Johnson Ternion AG	H.F. irradiation of dipolar substances to increase their energy content
472,671	Dufour and Leduc	H.F. vulcanization of rubber
472,764	Dufour and Leduc	Bonding of rubber to metal by induction heating
475,014	Descarsin Raimbault	H.F. fusing and welding of glass
483,832	Dupont de Nemours	H.F. cementing of shoe soles with thermoplastic adhesive
495 520	Dufour and Leduc	Bonding of rubber to metal by induction heating
505,389	Dufour and Leduc	H.F. heat treatment of rubber
513,022	Siemens-Schuckert, Berlin	Drying of paper by H.F.
517,798	Dufour, Leduc	H.F. heating of agglomerates. Preheating for moulding
518,517	Expanded Rubber Co.	H.F. for bubbling rubber and thermoplastic materials
519,053	Naamlooze Vennoots. Mats. Octrooien	Application of H.F. to glass blowing
540,494	British United Shoe Co.	Drying of shoe soles by H.F.
544,583	British United Shoe Co.	Drying of shoe parts by H.F.
545,173	Okonite Co.	Heat treatment of cable insulation by H.F.
547,562	Carborundum Co. of America	Bonding of abrasives in resins by H.F.
547,695 548,102 548,336	Okonite Co.	H.F. heat treatment of cable insulation
554,854	British Insulated Cables	H.F. treatment of cable insulation. 20-200 megacycles
555,054	Jarrard et al.	H.F. welding of thermoplastics, etc.
555,196	Jarrard et al.	Electrolytic field plotter
555,645	British Insulated Cables	Joining of thermoplastic materials by H.F.
557,203	Radio Corporation of America	Glueing of plywood by means of H.F.
558,064	Tyne Plywood Works Ltd.	Laminated plywood with adhesive cement softened by H.F. and consolidated under pressure

Patent Literature.—British (Contd.)

No.	Inventor	Subject matter
393,562	International General Electric Co.	R.F. heating of high dielectrics, pre-heating with gas.
417,427	B.T.H.	H.F. heating of plant bulbs in rotating drums
518,691	Patentverwertungs Gesellschaft Hermes	Drying of wood, paper, etc., by H.F.
554,176	British Insulated Cables	H.F. heating of sheet rubber for coating of wire.

U.S.A. Patents

No.	Inventor	Subject matter
1,806,846	Pittsburgh Plate Glass Co.	Laminations of glass-pyroxylin heated by H.F. and fused
1,900,573	General Electric Co.	H.F. heating of material in containers, conveyor system
1,998,332	General Electric Co.	H.F. heating of plant bulbs in rotating drums. 15 megacycles
2,079,708	United Shoe Machinery Corp.	H.F. drying of sponges in compression jig
2,087,480	United Shoe Machinery Corp.	Joining of shoe soles with thermoplastic adhesive and H.F. 30 megacycles
2,109,323	Compo Shoe Corp.	H.F. cementing of shoe parts
2,124,012	Thermal Engineering Co.	Reducing moisture in tobacco by means of H.F.
2,129,203	Dufour Leduc	Induction heating of rubber on steel, vulcanizing
2,147,689	Bell Telephone Co.	H.F. heating of dielectric materials. 1 rotating, 1 fixed electrode
2,179,261	Bell Telephone Co.	H.F. heating of moulding materials. Air gap between electrode and job
2,184,281	Armstrong Cork Co.	H.F. eddy current heating of crown seals for bottles
2,205,582	Telefunken	Welding and fusion of glass by H.F. Valve parts
2,222,615	United Shoe Corp.	H.F. joining of outsoles to shoes
2,231,457	Stephen	H.F. drying and heat treatment of plywood. Up to 50 megacycles
2,233,175	Carborundum Co. of America	Bonding of resin adhesive in sandpaper by H.F. Static, rotary drum, conveyor
2,233,176	Carborundum Co. of America	Resin bonding of grinding wheels by H.F. 10-50 megacycles
2,245,833	Thermal Engineering Co.	Altering moisture content of tobacco by H.F. treatment
2,249,855	United Shoe Machinery Corp.	H.F. sticking of shoe soles with thermoplastic cement
2,251,277	United Shoe Corp.	Drying shoes or shoe parts by H.F.
2,261,847	Dufour et. al.	H.F. heating and vulcanizing of rubber with and without metal inserts
2,280,771	Dufour Leduc	Vulcanizing rubber products by H.F. induction and dielectric heating. 10 megacycles
2,291,807	United Shoe Corp.	H.F. conveyor drying of skins and sheets
2,298,037	Compo Shoe Co.	Cementing and moulding shoe outsoles by means of H.F.
2,307,344	Girdler Corp.	H.F. bonding of sheet material
2,308,043	Radio Corp. of America	H.F. glueing of laminated wood. 10 megacycles and over

French Patents

No.	Inventor	Subject matter
804,595	Dufour Leduc	Induction heating of rubber
808,612	Dufour Leduc	H.F. heating and vulcanizing of rubber
848,467	Patentverwertungs Gesellschaft Hermes	H.F. vulcanization of rubber. 10 to 100 m. wavelength. Suprasonic vibration
848,468	Patentverwertungs Gesellschaft Hermes	H.F. vulcanization of rubber and L.F. heating. 3 megacycles and 50 c.

German Patents

No.	Inventor	Subject matter
633,455	Siemens-Schuckert Werke	Drying of wood by H.F. 5-50 m. wavelength
648,276	Siemens-Schuckert Werke	Drying of wood by H.F. Automatic control of plant. 5-50 m. waves
685,694	Dufour Leduc	Resistance and induction heating of rubber for vulcanization
695,707	Siemens-Schuckert Werke	Vulcanizing rubber by H.F. alternating fields

German Patents (Contd.)

No.	Inventor	Subject matter
698,566	Siemens-Schuckert Werke	H.F. bonding of glass and plastics (laminated glass). Pressure and L.F. heating of electrodes
699,372	Siemens-Schuckert Werke	H.F. heat treatment of rubber in continuous process
699,721	Siemens-Schuckert Werke	H.F. heat treatment of rubber in continuous process
715,632	Siemens-Schuckert Werke	H.F. heating of filled thermosetting materials in moulding press. 5-50 m. wavelength
734,486	Siemens-Schuckert Werke	H.F. drying and heat treatment of rubber, etc., in condenser fields
735,283	Siemens-Schuckert Werke	Vulcanizing of rubber by H.F. and mechanical (suprasonic) vibrations

War-blinded Press Operators

AT the invitation of Messrs. Halex, Ltd., we recently visited Hale End Works in company with the members of the St. Dunstan's Advisory Committee of the Moulders' Section of the British Plastics Federation. There we saw a war-blinded man operating a 70-ton hydraulic press, and this article tells you how this came about.

St. Dunstan's policy is to disperse the men (and women), blinded as a result of service in the present war, throughout a number of selected commercial, industrial and other occupations, and to place a limited number of suitable men, who can conveniently be absorbed by firms willing to employ them in the plastics industry. The Moulders' Section Advisory Committee has been formed under the chairmanship of Mr. E. T. White, to advise St. Dunstan's on matters concerning the training, placing and maintaining of their war-blinded trainees in the industry.

Knowing that St. Dunstan's were looking for an opportunity of demonstrating the possibility of using war-blinded men on the moulding of plastics powders, Halex, Ltd., offered to take such a man.

About the middle of October, St. Dunstan's sent to Halex, Ltd., J. Hancock, a man of 31, who, before the war, had been a metal machinist and who had been blinded while in the Army.

He was put on to a 70-ton press fitted with a nine-impression die for the safety cover of the No. 69 hand grenade. The forcer and die are both fixed to the press and the powder is loaded into the die in the form of pellets. The press itself is of the down-stroking type, with an efficient form of guard designed and made by Halex themselves. This not only prevents the hydraulic valves from being operated unless the guard is closed, but also swings in two blocks of wood when the press is open, so that, if the hydraulic power should fail and the ram begin to fall, it would immediately come to rest on the wooden blocks.

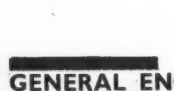
For the first three or four days " J.H." was under the care of Mr. A. E. Howlett, St. Dunstan's chief engineer, who built up for him a complete mental picture of the job and its surroundings. The shop charge hand, who was also instructing him in the job, found that he was very quick to master all the details, and after a few days it was left to an operator near by just to keep an eye on him.

He reached his full output after six weeks' work, which is shorter than the time normally taken by an unskilled man. His rate of output is equal to that of an experienced sighted man, and he has no difficulty whatever in maintaining it. His good output is no doubt due to his power of concentration on the job and his keenness, and, perhaps, also to the fact that he has to work to a regular rhythm, since he cannot use the clock on the press.

(Continued on page 146)

World's Industry Employs Plastics

GENERAL ENGINEERING



Sealing of porous castings to attain gas tightness is said to be accomplished by impregnation with polyvinyl chloride or polystyrene. These materials are said to show properties superior to many of those hitherto used. Insulating spacers between metal parts, particularly for prefabricated structures, such as refrigerators, are made of a plastic with low heat conductivity and low moisture absorption capacity. Permanent insulation properties are obtained in this way, and metal-to-metal contact of any type is eliminated. It is suggested that the spacers can be employed as a substitute for the more usual fillers or packing between metal sheets and panels in this type of structure (providing the air space be maintained at a critical minimum it would seem that this system could be embodied in the metal units of post-war steel buildings). An American concern, Lindsay and Lindsay, are producing tubular spacers in phenolic plastics with ends tapped for fastening bolts. **Relationship between available tools and design of moulded plastic parts** is considered by Delmonte in a recent issue of "Machine Design," in which is also featured a data sheet on paper-base laminated phenolics. Mechanical figures, such as tensile strength, comprehensive strength, bend strength, sheer strength, impact strength, elastic modulus, rockwell hardness, water absorption, electrical properties, etc., are detailed. Machining qualities are also noted. **Working of plastics** is covered in a comprehensive supplement to "The Machinist," 1944, Vol. 87, January 15. Both thermosetting and thermoplastic resins are treated, the review being compiled from contributions by a number of tool and plastic concerns; mould design, the construction, machining and finishing of plastics are also dealt with. **High-frequency pre-heating of plastics** is dealt with in "Mechanical World," 1944, Vol. 116, p. 63. The account deals chiefly with new electronic devices for the industrial production of frequency heating currents. (The equipment discussed is manufactured by the Radio Corporation of America.) **Marking of metal and non-metal substances,** such as plastics, glass, wood and hard rubber, is conveniently carried out with an electric pencil operating at 1,000 strokes per minute, stroke being adjustable for shallow or deep cuts. The tool, which may be employed as rapidly as an ordinary pencil, is manufactured by Breuer Electric Manufacturing Co. No. 5, 100 North Ravenswood Avenue, Chicago. **Relationship between chemical composition and strength properties of plastics** is discussed by Hasselbarth Smekal, "Künststoff Techn. und Anwendung," 1943/13/33. The authors show that relationship between composition and mechanical properties is influenced by methods of sample production and by test conditions. For this reason the latter were reduced to their simplest form, i.e., pure tensile strength with uniform increase in load samples of cylindrical form and surface finish of reproduceable quality. Tensile tests were carried out with extruded sections of polystyrene (Trolitul) 6 mm. in dia. and on 4-5-mm. dia. bars of polystyrene, subjected to previous hot extension (Styroflex). When the test was carried out at low rates of stress increase (5 gm. per sq. mm. per sec.), fractures were observed to occur below the nominal tensile limit. The micro-structure of the fractured surfaces was investigated.

Present and post-war advantages of plastic dies and die sets are discussed by Cook in a comprehensive article in "The Tool Engineer," 1943/12/72. The author, it is claimed, is a pioneer authority on forming, blanking and perforating with lightweight plastic dies. **Intricate cellular construction in plastic parts** is now possible, according to an account in "Product Engineering," December, 1943. The cavities are formed by means of sand cores wrapped in waxed paper, which give the necessary smooth surface for the production of the required wall characteristics in the plastic cell.

AIRCRAFT

New-type aeroplane Propellers composed of metal core, with fairing of hard sponge rubber and covered with neoprene, are stated to be extremely light and to be capable of withstanding stresses of 60 tons in flight. Resistance to surface wear is such that the propeller is said not only to withstand impact of rain and sleet but also chance impact from sand particles, etc. Safe working range extends from −70 to +140 degrees F. Delamination of plywood forms the subject of certain established tests, which, according to Muhlenbruch, suffer from certain disadvantages. The author claims that actual physical test for modulus of rupture or modulus of elasticity will produce a quantitative measurement of loss in strength, due to wetting, and consequently a figure for liability to delamination. The superiority of these tests compared with the normal quantitative vision test is proved (Transactions, ASME, 1943/65/723). **Dynamic of rubber or plastics** resulting in deterioration and breakdown may be caused by prolonged vibration. It is known that under a constant load below its tensile strength rubber will fail by "static" fatigue. In practical applications both types of loading are combined. F. L. Yost, of U.S. Rubber Co., Detroit, has made quantitative studies on rubber and plastics in an investigation of both types of failure (Transactions, ASME, 1943/65/881). **Use of Tenite (cellulose acetate) shot** has been found practical by the U.S. Army Air Force for decarbonizing piston skirts and piston ring grooves. As contrasted with sand or steel shot no material wear is caused to the metal. "Tenite 1" with maximum grain size $\frac{1}{16}$ in. is used. The plastic shot is manufactured specially for this purpose by the Tennessee Eastman Corporation ("Transport Topics," Monday, December 20, 1943, p. 4). **Use of newer types of thermoplastics in place of shellac compositions** for gramophone records in the post-war period was visualized by Dutton in a discussion before the wireless section of the Institution of Electrical Engineers, Feb. 15, 1944.

ELECTRICAL

Brushes with plastic bristles tend to acquire static charges often 10 times as great as those made with hog bristles. On one set of bristles at 16.4 degrees C. and 37 per cent. relative humidity a maximum charge of 7,200-8,200 volts was measured. Whilst it was shown to be impossible to cause explosions by sparks drawn directly from plastic bristles, nevertheless, induction effects from such charges can induce dangerous charges in nearby insulated metal parts. The discharge from these metal parts may cause explosions (Broihan, "Wärme," Vol. 65, p. 266). **Polyvinyl chloride insulating sleeving** in place of natural rubber forms the subject of Swiss patent 224,488 recently granted to Paul Hellermann, Hamburg. The sole claim of interest in the patent seems to be that the polyvinyl chloride employed can undergo great extension when heated to 60 degrees C.

Metallizing Plastics
(continued)

A Complete Survey and Critical Study of the Modern Methods of Metal Film Formation on Plastics for their Protection and Decoration

by
E. E. HALLS

9 and 10.—Metal Coatings Electrically Sputtered or Thermally Evaporated in Vacuum

THE major purpose of cathode sputtering and vacuum evaporation processes is the production of metal films upon the surfaces of articles, of metallic or non-metallic nature. Thoughts immediately turn to other established methods that have the same object and to wonder whether these newer processes substitute or complement the older ones. In point of fact, cathode sputtering and vacuum evaporation are two additional processes in engineering. By their means, objects can be achieved that would otherwise be either impracticable or not practicable with anything like the same degree of efficiency.

Electrical sputtering and thermal evaporation are advantageous in specific applications for the production of metal films in vacuo. They are ideal in many cases, especially when the material to be coated is not metallic. Their widest application has, perhaps, been for glass, quartz and ceramic, and the chief purpose of the films so produced has been for electrical conductance or for optical reflection or transmission. Gold and silver films produced by sputtering are regarded as ideal for electrical contact between the metal electrodes and non-metallic dielectrics in electrical testing, particularly for power factor and permittivity measurements. High-frequency testing, even at one to ten megacycles, has often made such films desirable, but the use of ultra-short waves has caused test sets to be developed to cater for the ranges of 5 to 200 and 200 to 1,000 megacycles. It is evident that ensurance of accurate contact between material and electrodes becomes an acute problem, and the vacuum-produced films can be expected to be more generally recognized.

So far as can be ascertained the vacuum-produced films are not extensively employed on plastics in this country in strictly industrial applications. Sputtered gold and silver coatings on plastics, including the hard rubbers and phenolic laminated and moulded products, are used for power factor and permittivity measurements. Zinc coatings were at one time similarly produced on paper of the very fine grade used for electrical condensers, this on a small industrial scale, and attention is being given to tin and aluminium in the same connection because of the obvious merits of such material and the large market for it. This is mentioned because, likewise on a small scale, attempts were made to produce zinc-coated cellulose-acetate film by electrical sputtering, without commercial success. This was probably due to the attempt being premature, before, in fact, thin electrical grades of cellulose-acetate film had been established. With the ready availability of cellulose-acetate film to-day, and the promise of polystyrene, ethyl cellulose and polythene films after the war, work should be re-opened on vacuum metal coatings on these materials. In America, somewhat greater progress has been made, and it is understood that transparent plastics are coated with silver by vacuum evaporation. The chief application is in relation to optical properties, and apparently the methyl methacrylate

resin type is the chief so treated. Information appertaining to this is available from the American Silver Producer's Project, through Messrs. Handy and Harman. Again, special silica-loaded polystyrene compositions are becoming established, not as substitutes for, but as superseders of, high-frequency low-loss ceramics, chiefly on account of their greater manipulability or mouldability to closer dimensional accuracy and superior shock strength. Sputtered or evaporated films on components in this material are often desirable, if not essential, and are sure to become commonly recognized in electrical industry.

It will be seen that at the moment little or nothing can be said concerning the industrial uses of these metallizing processes on plastics, but their importance demands their inclusion in the present survey of metallizing. Moreover, this procedure is justified by the interest taken in the possibilities of the processes, by the need that already exists for them, as well as by the desirability to make clear all that is involved. In this way, the specific nature of sputtering and evaporation can be impressed upon prospective users, and the fact that these processes do not compete with metal spraying in particular or with the other methods dealt with in general, can be made evident. Consequently, close attention will be given to the use of the vacuum-produced films and to the science of their production. This should serve as a useful starting point for the many who to-day are interested in the practical aspect of metallizing plastics by these means.

Sputtering, etc., Produces Films Not Obtained by Other Processes

Perhaps the most universal method of metal coating is that of electroplating. In this, the work to be treated must be capable of passing through a series of aqueous chemical cleaning solutions, of forming the conducting cathode in a suitable electrolyte, and finally of being washed free from the electrolyte. Thus the work must be metallic, or it must be practicable to apply a conducting surface to it. Further, it must be non-absorptive, otherwise chemical solutions become absorbed in it and it is impossible to wash them free. Later, they seep out gradually and ruin the deposit. Another widely utilized process is that of hot dipping, in which work suitably prepared and meticulously clean is coated by immersion in the molten metal. In the main, this is restricted to a few metals of relatively low melting point (tin, soft solders, zinc), and the nature of the preparatory treatment of the work, which includes acid fluxing, confines the application of this type of process to metal work. Non-metals as well as metals are catered for, however, by hot metal spray processes. In these, the metal to be deposited is applied from the liquid state by atomizing with compressed air (or other suitable gas) and directing upon the surfaces to be coated by means of specially designed guns.

All these processes serve many purposes admirably, but have shortcomings for others, these shortcomings often being sufficiently serious to preclude their use. The electroplate processes give relatively uneven coatings and it is difficult to plate part only of a surface; further, there is always a tendency for plating chemicals to be retained in the somewhat porous coating, despite thorough washing. Hot dipping tends to give uneven coatings; a specified portion of a surface cannot be so treated. Hot spray gives relatively thick coatings, they are of even but rough texture.

Other methods have been developed which, in a few instances, overcome these drawbacks. One such method is that of "burning-on" or firing. It is confined to the deposition of a few noble metals (platinum, gold, silver) applied as film by igniting an appropriately formulated compound upon the surface in question. Temperatures concerned range from 260 to 1,100 degrees C., so that materials such as ceramics, some glasses, micas and the like, are the only ones to which it applies. Another method is chemical deposition in which a very thin coating of a metal is deposited by chemical reaction (e.g., silvering of glass)

or by replacement (e.g., tinning of brass). Precleaning must be perfect, chemicals are involved, and subsequent washing must be thorough.

Broadly speaking, none of these processes can give deposits having the combined properties of thinness, uniformity, purity and adherence exhibited by sputtered or evaporated films. These latter processes have been worked out for more elements than have any of the other processes. Moreover, they can be applied to any materials, conducting or non-conducting. They are specially suitable for ceramics, quartz, glass and plastics. They can be applied to part surfaces relatively easily and to objects that would be too small for coating by other means. Controlled thickness from "invisible" to something quite positive is practicable, and chemical cleanliness of the product is assured. It is evident, therefore, that they have specialized applications and opened up new industrial fields.

Growing Industrial Interest in Sputtering

From the scientific point of view, the phenomena of cathode sputtering and of vacuum evaporation, with particular reference to the formation of thin, continuous metallic films, are well known and much research effort has been expended upon them. Commercially, these processes have been operated for many years for specific purposes, but during the past few years industrialists have been considerably more interested in them. In fact, there are a number of instances where they figure as essential operations in production lines of mass-produced articles. The processes are somewhat involved scientifically, yet when the equipment required is planned with care and operated under properly controlled conditions, no obscure problems or undue difficulties arise in practice. Broadly speaking, they are used to produce films of "pure elements" upon objects that may be metallic or non-metallic, the films being controlled in thickness and uniformity to provide specific characteristics of electrical conductivity, capacitance, etc., or of optical reflection or transmission. Their obvious primary fields of application are therefore electrical or optical, and the industries concerned are usually the more highly specialized ones concerned with instruments and apparatus. More specially, they are also employed for the deposition of films of chemical compounds (e.g., quartz), or of alloys or metal mixtures (e.g., aluminium/magnesium). Established commercial applications include the following:—

Cathode Sputtering.—Gold or platinum metals sputtered as thin films transparent to light on to selenium coatings to provide low-resistance electrical contact for photo-electric cells. Gold sputtered in thin films on to copper oxide-type rectifier discs, for electrical contact. Gold or silver sputtered in relatively thick films on to ceramic base, especially low-loss type, for fixed and variable condensers. Gold or silver sputtered on to precision-ground quartz crystals for oscillators.

Vacuum Evaporation.—Aluminium or silver evaporated on to quartz crystals for oscillators, for contact and capacity reasons. Aluminium evaporated on to glass and quartz, and on to transparent plastics, for optical reasons, e.g., for internal mirrors of infra-red lamps for radiant heat equipment. Selenium evaporated on to aluminium or steel plates for discs for rectifier or photo cell elements.

Numerous industrial applications occur in connection not with production but with inspection and testing. Excellent electrical contact can be obtained in this manner with the contacting film in intimate contact with the base material. Hence this method is frequently standardized upon for producing contacts on insulating materials, the ebonites, bakelites and ceramics, for the test pieces subjected to electric strength, power factor, permittivity and insulation tests, especially for tests made at high frequencies. Sputtered silver films are generally used in this way upon low-loss ceramics.

In consequence of these numerous com-

mercial applications and the rapidly increasing fields in industry for the unique properties of thin films, a review of the salient features from the literature and established practices is considered apt for those wishing to extend their application to plastics.

Electrical cathode sputtering is effected in a rarefied atmosphere between two electrodes. One of these, the cathode, is the material to be deposited as a sputtered film. The other, the anode, is of suitable material. The cathode is maintained at a high negative potential with respect to the anode, and an intense electrostatic field is created between them. In this field, the relatively heavy positive ions of residual gas, directed towards the cathode, impact upon it and dislodge or tear out particles of material from it. These particles are probably of molecular dimensions, and carry a negative charge, and therefore travel towards the anode along the electro-static field. If an object, or number of objects, are placed between the cathode and anode in the electrostatic field, they will be situated in the path of this stream of negatively charged cathode particles. The particles thus become mechanically intercepted or filtered from the stream, and the object becomes coated with the cathode material. By arranging for uniformity of field, and placement of the objects in that portion of the field that is uniform (that is, constant number of lines of electrostatic force per sq. in. of cross section), a uniformly cathode sputtered layer can be built up. The thickness of this layer is determined by the total time period of the operation.

Thermal evaporation is accomplished in a rarefied atmosphere, but is not so involved as cathode sputtering in that it is a simple problem of evaporation by thermal means. The vacuum is required for preventing oxidation and incidentally for lowering of boiling point. The thermal means are dependent upon the material to be evaporated and the objects to be coated. Electrical heating means are almost universal, and for some materials and purposes a refractory crucible, boat, basin or tube wound with an electrical element suffices. For others, the material is actually evaporated from a coil or filament rapidly raised to temperature by a current of electricity passed through it.

It will immediately be appreciated, therefore, that cathode sputtering is an electronic discharge effect, and is in marked contrast with evaporation, which is a straightforward physico-mechanical phenomenon. Sputtering, by virtue of the fact that films are built up by molecular deposition, is a relatively slow process, is convenient for providing exceptionally thin coatings, but should be capable of control to ensure complete uniformity and continuity. Evaporation on the other hand is relatively rapid, and thickness of film is controllable by quantity of material evaporated. It would be expected that control of uniformity and the production of thin films by this method would not be so easy as with the cathode sputtering method. It is also pointed out that sputtering requires a vacuum of the order of 0.05 to 0.10 mm. of pressure, whereas evaporation operates at lower values of 10-4 to 10-5 mm.

With these brief preliminary explanations and comparisons of the two processes, they will now be considered in some detail. Established methods and practical requirements will be stated and discussed, dealing first with sputtering.

Cathode Sputtering

From the introductory information presented, it will be seen that the essential items of plant for cathode sputtering will comprise the following:—

(a) A chamber capable of withstanding and maintaining a high vacuum. This chamber has to be provided with two electrodes, the leads of which pass through the chamber, but insulated from it, to the electrical supply.

(b) A pumping equipment capable of producing and maintaining the high vacuum required.

(c) An electric supply or machine to provide high voltage, up to a value of the order of 10,000 volts. It is obvious

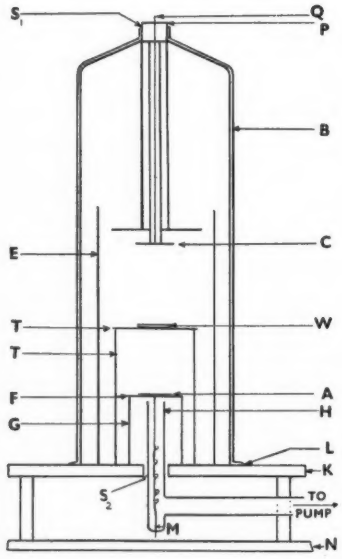


Fig. 24.—Components, design and construction of cathode sputtering apparatus. (For key see text.)

that the number of variables in the process is large, and that factors such as degree of vacuum, nature of residual gas (air, nitrogen, argon, etc.), voltage and current density, composition of cathode and anode, shapes and positions of cathode and anode, position of the work, and surface preparation and cleanliness of electrodes and of work, give much scope for experimental work before best conditions can be stated. The general procedure, with some knowledge of the technicalities involved, appears to be to study the scientific publications on the subject, from this to derive the general design of the plant required, and, finally, to work out optimum conditions for the specific job.

The technique of cathode sputtering established by the Naval Research Laboratory and given in a paper to the Optical Society of America, 21/10/1933, by E. O. Hulburt, and published in Rev. of Sci. Instr., Feb., 1934, as as follows:—

Fig. 24 shows diagrammatically the apparatus employed, this being designed for as universal use as possible, that is, adaptability to take various anodes and to sputter various objects. At the same time, simplicity is the outstanding feature in its construction. The diagram is approximately to scale. The sputtering chamber consists of the glass bell jar (B) approximately 40 cm. high by 18 cm. dia., having its flanged bottom periphery ground to fit on the heavy glass base-plate (K). The junction (L) is made vacuum-tight with stop-cock grease. The assembly is supported on the strong wooden base fixture (N). Connection to the vacuum pump is made through the glass tube (H), which passes through the centre of the glass base-plate and is sealed into it by means of vacuum wax at S2. Through this tube also is taken the electrical lead to the anode, that is, a sealed-in electrode at M connected by a flexible aluminium wire to the anode plate of aluminium (A). The latter is supported on a glass disc (F), which in turn is held on the glass cylinder (G). To promote reasonably rapid evacuation, a gap of about 1 mm. is left between the extremity of the glass tube (H) and the glass plate (F), and the junctions between the glass plate (F), the tube (G) and the baseplate (K) are relatively loose ones.

The cathode assembly enters through the top tubulure of the bell jar. The cathode (C) is fixed to an aluminium rod (Q), which fits into the metal plug (P). The latter is " permanently " fixed in the bell jar, being sealed externally by means of vacuum wax at S1. The cathode and its supporting rod are shielded by a glass disc and two glass sleeves respectively.

Work (W) to be sputtered is supported on the table (T), this usually being of glass, although it can be of aluminium wire. It will be noted that the equipment is assembled for sputtering downwards, but it can be easily arranged with the cathode (C) and anode (A) reversed in position for sputtering upwards.

The function of the shielding glass sleeves and discs is to confine the discharge as nearly as practicable to the space between the anode and cathode.

They prevent the discharge plating upon metal connections to the electrodes and upon the seals. This has to be avoided as otherwise liberation of gas, that upsets fixed conditions and makes control impracticable, would occur.

The complete apparatus is easily assembled and disassembled for cleaning. Also, a further protecting glass tube can be incorporated when desired, viz., E. This minimizes discharge from cathode to the bell jar and is advised when sputtering an element that is difficult to remove, e.g., silicon.

General Working Conditions and Precautions

The current supply may be rectified or unrectified, voltage from 1,000 to 3,000 volts and currents 25 to 50 milliamperes. At the higher powers it is desirable to cool the set-up externally by means of a fan. It should be noted that at powers greater than 100 watts excessive heating may occur, and poor-sputtered films and difficulty in maintaining seals may result.

Occasions arise when exceptional purity of film is required, and this can be further ensured by using the same metal for anode (A) and cathode (C). In these circumstances, the work can be so placed that it receives its deposit from either A or C or, indeed, from both A and C.

An approximately correct working rule states that best films are obtained if the pressure is maintained such that the edge of the Crooke's cathode dark space is roughly tangent to the object to be sputtered. Nevertheless, this is not critical, as shown by the following experimental result obtained by Hulburt. A series of glass plates were arranged 1 cm. apart in front of the cathode, and the dark space was maintained 4 cm. from the cathode. The quantity of deposit on the plates at 2, 3 and 4 cm. was approximately the same, and at 5, 6, 7 and 8 cm. was progressively less. The plate at 1 cm. was too near the discharge to be uniformly covered, due to interference with the discharge, the coating being thicker around the edges and thinner in the centre. It should be noted, too, that the plates received some deposit on their faces remote from the cathode, although only slight. This phenomenon is a common one, especially when sputtering slowly. The deposit on the remote face is usually more uniform, although, of course, thinner than that on the near side.

Every care has to be taken to have everything chemically clean, particularly the cathode. This can be cleaned chemically or by means of abrasive glass paper, but must be free from grease, including finger marks. Hulburt notes, in common with other workers, that when a cathode is first used the deposit may be slow in coming down, but after an hour or more this rate increases. The surface of the cathode appears to become in a more readily sputterable condition, which is retained even if the cathode is removed, exposed to air and refitted, providing its surface is not handled or contaminated in any way.

Hulburt records relative speeds of sputtering various metals in this apparatus under the following conditions:—A residual gas atmosphere of air corresponding to a dark space of 5 cm., total current 50 milliamperes, cathode diameter 5 cm. They are summarized below:—

(a) Opaque coating formed in about 1 hour. Antimony, bismuth, cadmium, gold, lead, platinum, silver, tin, zinc.

(b) Opaque coating formed in about 2 hours. Cobalt, copper, iridium, iron, nickel, selenium, tellurium.

(c) Metals that require several hours to give an opaque coating. Molybdenum, tantalum, tungsten.

(d) Metals that sputter extremely slowly. Aluminium, beryllium, carbon, chromium, magnesium, silicon.

In the cases of aluminium, chromium and silicon, the rate of sputtering is increased enormously by the introduction of mercury vapour, helium or argon into the sputtering chamber. In this manner, optically perfect opaque films can be obtained in less than 15 hours.

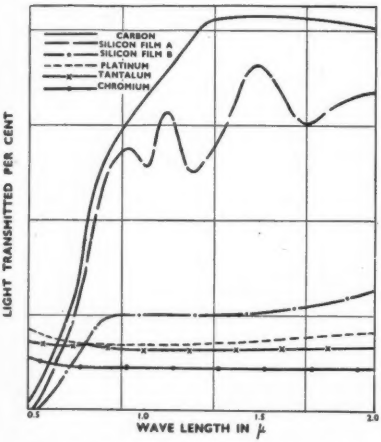


Fig. 25.—Per cent. light transmitted by sputtered films for various wave lengths.

The influence of these monatomic gases in this direction is not explained. With beryllium and residual gas of hydrogen and mercury vapour 60 hours failed to produce entirely opaque films, although they were optically good. In this case both electrodes (A and C) were of beryllium, the glass plate coated was in position (W), while small glass plates placed along A received opaque coatings in 20 hours.

With the residual gas consisting of air, graphite (both electrodes) gave nearly opaque films in 30 hours and mercury vapour did not improve the rate. The films were uniform, optically smooth, blackish in reflected light, and the thinner coatings yellowish in transmitted light. They were moderately soft.

The flexibility of the form of apparatus described is illustrated by the several cathode arrangements that can be adopted with a flat cathode plate fixed vertically, the objects to be coated can be positioned on either side of it and the two loads of work receive their deposit simultaneously. Using a vertically positioned cathode in the shape of a wide U, an object within it can be coated on opposite sides in the one operation. Again, using a wire-form cathode the internal surfaces of a tube can be coated. It is evident, however, that individual difficulties have to be solved. For example, in coating tubes, as the length becomes greater than the diameter, the uniformity of the coating becomes less due to the discharge from the anode not reaching all points on the cathode wire.

Hulburt speculates that the discharge from the cathode is of atomic dimensions and that much of it proceeds in straight lines from the cathode. This is shown by the fairly well-defined shadows that can be cast upon an object by interposing an obstacle such as a diaphragm. The "shadowed area" receives no deposit, or very little. On the other hand, the walls of the vessel and all the remote surfaces of fixtures, etc., within the chamber receive some deposit, much being due presumably to diffusion. Complex interference effects were recorded. When the cathode emission was passed through a hole 2 mm. in diameter in a glass plate 2 mm. thick to fall on a glass plate 3 mm. distant from the tube, a film was formed roughly the geometrical shadow of the whole but having an uncoated central spot.

The films obtained from some elements in the manner described were tested for optical transmission in the visible and near-infra-red regions. Results are summarized graphically in Fig. 25. It will be seen that the transmissions for platinum, tantalum and chromium are approximately constant over these wave lengths, but that for silicon and carbon the films are more transparent to the longer waves. The light not transmitted is probably mainly reflected and a little absorbed. The colour of the silicon film used for the curve (A) in Fig. 25 was orange in transmitted light. The irregular kinks in the curve are explained by interference in reflection from back and front surfaces of the film. The silicon film used for curve B was a thicker one and was a deep red colour by transmitted light.

The cathode sputtering chamber developed in researches by G. L. di Ombrain and C. L. Fortescue at City and

Guild's College is shown in Fig. 26. The anode (A) consists of an aluminium plate of appropriate size and of sufficient area to dissipate the heat developed in it. The cathode plate (C) parallel to the anode is of the material to be sputtered. It is about the same surface area as the object to be coated. This object is supported from the pillar (S) in a plane approximately parallel to that of the cathode. It will be noted that the object is on the side of the cathode remote from the anode. Argon, recommended for sputtering any easily oxidizable metals, was used for the atmosphere and at a pressure that gave a cathode dark space of from 1 to 2 cms. at a supply voltage adjusted to give a current density from 2 to 3 milliamperes per sq. cm. of cathode surface. The position recommended for the surface to be covered is about 0.5 cm. beyond the end of the dark space. About 1,000 volts is required between the electrodes, with a series resistance having a similar voltage drop between its ends in order to control the discharge.

Uniformity of the cathode sputtered layer is checked by depositing on glass and examining in transmitted light. It was found that the apparatus gave very uniform films when operated as recommended, but with the object positioned between the electrodes the film was very uneven.

The form of chamber and vacuum system can be of any type that gives the results required. These workers used a glass bell jar with ground flange on a firm brass base plate, the junctions being held vacuum-tight by means of Apeizon compounds.

Films were deposited upon metals or non-metals (plastics, glass, ceramics). They were strongly adherent, markedly more so than sprayed or electro-plated metal coatings, or metal coatings applied from colloidal solutions and baked. The rate of formation of sputtering films was of the order of $1\frac{1}{2}$ cm. by 10^{-6} in 10 mins. for copper and one-tenth of this for gold. These thicknesses were calculated from resistance determinations and assume the specific resistance of the metal to be the same as in the normal solid condition.

In using the apparatus, it is first flushed with argon several times. To do this, the electrodes and object are mounted in position, and the chamber sealed and pumped to the maximum vacuum attainable with the pumping system. A few ml. of argon are admitted and the system repumped. This is repeated several times. Finally, argon is

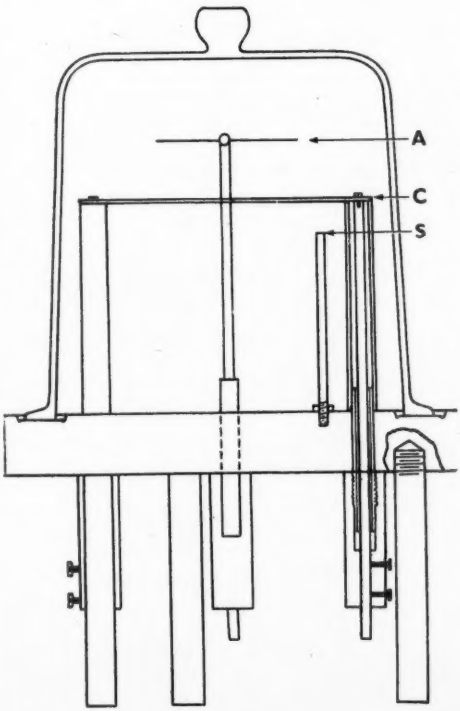


Fig. 26.—Another form of sputtering apparatus. (See text for key.)

admitted, and the chamber pumped until a satisfactory discharge is obtained, 2 to 3 milliamperes per sq. cm. of cathode and a dark space of about 1.5 cm. This discharge is continued to give the deposit as may be necessary. Air leakage has to be avoided or films of oxidizable metals will be tarnished.

Vacuum-tight joints are ensured by the usual grinding-in processes, e.g., with paraffin and emery powder. The brass base plate can be tinned. The work to be coated will become hot from thermal radiation from the adjacent cathode. If the work can thereby become physically harmed (e.g., plastics), sputtering must be intermittent, allowing intervals for cooling. Areas not required to be sputtered can be masked by means of closely fitting screens. Shadows can form due to " straight line " cathode emission. Thus, in electrical coatings, terminal tags often need to be fitted after sputtering owing to the line shadow tending to form around the periphery of the terminal.

The exhausting arrangements recommended for this equipment utilize a small Hyvac pump driven by a 1/6 h.p. motor. The capacity of such a pump is 7 litres per min., and it can maintain a vacuum of 0.0004 mm. of mercury. The pump is

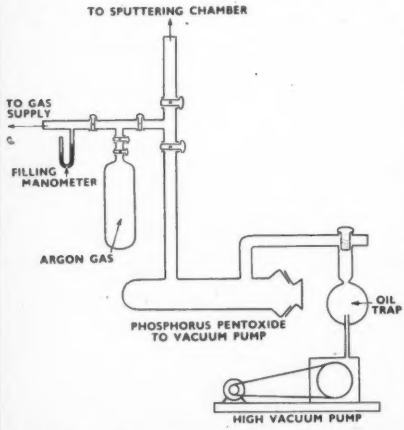


Fig. 27.—Pumping system, oil and moisture traps and gas-filling device for sputtering apparatus.

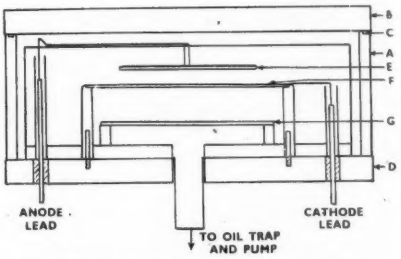


Fig. 28.—Commercial cathode sputtering apparatus.

connected to the equipment through an oil trap and a phosphorus pentoxide drying chamber for removing moisture, and to the argon supply line. The arrangement is shown in Fig. 27.

The electrical supply comprises a generator to give 250 milliamperes at 2,000 volts, with a field control to reduce the latter to 500 volts. A slide wire resistance, as mentioned above, value about 3,000 ohms, in series acts as a ballast resistance and reduces the voltage immediately the discharge strikes. Vacuum and voltage control gives all that is required to provide the dark space and current density required for specific purposes.

The form of cathode sputtering apparatus may be modified to suit particular needs of metal to be sputtered, articles to be coated and purpose for which the film is needed. One such commercial equipment used for gold and silver sputtered on to ceramics, glass, metal, bakelite, etc., and applicable to the sputtering of other elements, is shown diagrammatically in Fig. 28. It will be noted that the orthodox bell jar type of container has been replaced by a cylinder with an easily removable top plate. The chamber thus comprises a heavy cast-iron cylindrical vessel (A) with open ends, efficiently glazed inside with a vitreous enamel coating. Top and bottom flanges are ground to fit their respective plates. The top cover plate (B) is of plate glass, about 1 in. thick, with ground periphery, although the seal is ensured by a rubber gasket (C) let into the flange on the

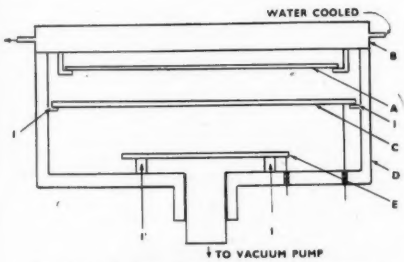


Fig. 29.—Commercial sputtering apparatus with annular anode.

cylinder. No grease seal is used at this junction. The removable glass cover plate permits of easy access to the equipment for loading or unloading, as well as of observations during working. The base plate (D) is of ground steel, and a vacuum junction is secured with the minimum of Apiezon grease. Supporting pillars are screwed into the plate, electrical leads pass through but are insulated from it, and from the centre the lead to the vacuum pump is taken. It is covered inside by means of a loose plate of $\frac{1}{2}$-in. plate glass. The anode (E) is of aluminium, the cathode (F) is either of the material to be sputtered or of specially polished brass electroplated with the material to be sputtered. The electroplate coating must be uniform and continuous and free from defects. The work platform (G) is of glass, positioned on the side of the cathode remote from the anode. It is parallel to the cathode and of about the same area. Metal supports as well as electrical leads are protected with tubular glass shields. The anode is suspended from a metal rod which passes through a glass plate, supported on four metal pillars. A metal strip connection from the central fixing to near the edge of the plate enables a wire connection from the lead in the base to complete the anode electrical circuit. In other respects, the equipment is similar to those already described, with high-voltage electrical supply through a series resistance, and with a pump system, sometimes merely a Hyvac type of oil pump, sometimes with oil trap and drying chamber included. The residual pressure is of the order of 0.1 mm. of mercury or less. Using the apparatus, everything is meticulously cleaned with benzene or other suitable solvent.

U.S.A. patent No. 663,731 covers the use of palladium as a sputtered coating for the wax masters of phonograph records. Gold or silver has been employed for this purpose, but palladium is less expensive, quicker in sputtering, harder and less tarnishable, but, above all, it does not possess the shortcoming of tending to diffuse into the electroplated copper matrix. It is to be noted that this enables non-conducting materials to be easily electroplated and thick metal coverings to be built up by normal plating processes. The recording process consists in inscribing the spirally cut sound track upon a homogeneous wax surface, then sputtering the latter with a thin

Fig. 30 A. Wax master

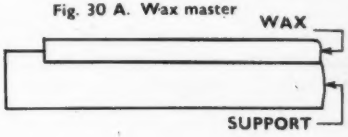


Fig. 30 B. Palladium sputtered on wax master

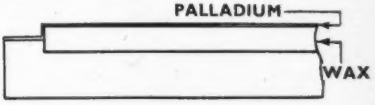


Fig. 30 C. After copper plating

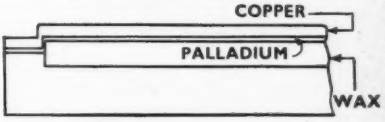


Fig. 30 D. Palladium copper negative

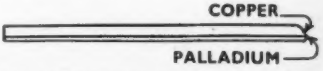


Fig. 30.—Wax master, palladium sputtered and copper-plated.

metal coating to render it electrically conducting, then electroplating with copper. The copper negative is removed and the plastic record is obtained from it by pressure methods, using cellulose acetate or other thermoplastic. It is during this process that the sputtered metal, if diffused into the copper, can cause damage to the positive cast by roughening the surface of it. About 1 ton/sq. in. at 150 degrees is employed. The effective surface of the negative is palladium, which can be thin but smooth and continuous, contrasting with gold and silver, which are relatively rough, due to diffusion. In the sputtering process, water cooling has to be employed to prevent damage to the wax base from the heat produced. A pressure of the order of 0.05 mm. of mercury is used and sputtering is continued for about 10 minutes. The technique is of interest because the object to be sprayed is positioned on the side of the anode remote from the cathode, and an annular aluminium anode is employed. The arrangement of the sputtering chamber is shown in Fig. 29. In this, the wax record (A) is supported from the watercooled cover (B) of the equipment. The annular anode is

Table 38.—Sputtering Rates of Metals.

Observer	Gas	Rate of sputtering in descending order
Crookes ..	Air	Pd, Au, Ag, Pb, Sn, Pt, Cu, Cd, Ni, Ir, Fe, Al, Mg
Kohlschutter ..	N_2	Ag, Au, Pt, Pd, Cu, Ni
Blechschmidt ..	A	Cd, Ag, Pb, Au, Sb, Sn, Bi, Cu, Pt, Ni, Fe, W, Zn, Si, Al, Mg
Güntherschulze	H_2	Bi 1,470, Te 1,200, As 1,100, Tl 1,080, Sb 890, Ag 740, Au 460, Pb 400, Zn 340, Cu 300, C 262, Sn 196, Fe 68, Ni 65, W 57, Co 56, Mo 56, Mn 38, Cd 32, Al 29, Cr 27, Ta 16, Mg 9
Güntherschulze	O_2	Zn 1,030, Tl 650, Ag 614, Au 423, Pb 320, Cu 236, Sn 227, Fe 86, Mo 80, W 49, Ni 52, Cd 28

Crookes, Sir W., Roy. Soc., Proc., 50, 88 (1891).

Kohlschutter, V., Zeits. f. Elektrochem, 15, 316 (1909), Jahrb. Radioaktivitat, 9, 335 (1912).

Güntherschulze, A., Zeits. f. Physik, 36, 563 (1926), 38, 575 (1926).

(The Güntherschulze numbers give rate of sputtering in milligrams per ampere hour under conditions of cathode fall of 770 volts and current density of about 7 milliamperes/cm.2.)

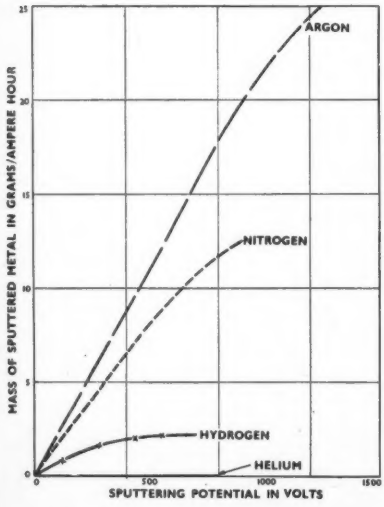


Fig. 31.—Influence of nature of residual gas on sputtering rate of silver.

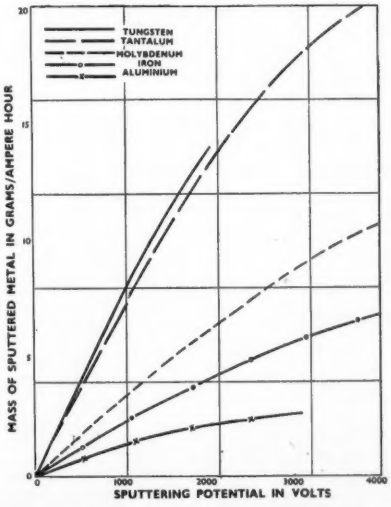


Fig. 32.—Showing relation between sputtering rate and potential for various metals.

supported from insulators on the walls of the inverted bell-shaped vessel (D), the latter being, for example, of vitreous-enamelled cast iron. The cathode (E) is glass, palladium coated, also supported on insulators. Fig. 30A shows the wax form on its metal support, 30B the palladium-sputtered form, and 30C after copper-plating. Fig. 30D shows the copper-palladium negative ready for the plastic pressing operation.

Information upon the relative rates of sputtering of various metals, as recorded by several observers, is concisely summarized in Table 38. This is self explanatory, and not only gives the relative sputtering order of the various metals but also indicates the rate of build-up of thickness for them. Bearing in mind the currents actually employed, the slowness of deposition is apparent, and the suitability of the process for very thin films rather than for thick ones is emphasized. Further information upon this is conveyed by the curves given in Figs. 31 and 32. The first of these show the marked influence of residual gas upon the sputtering rate of silver. The second of them illustrates the marked difference for several metals at different voltages. Both are drawn from Guntherschultze's data; the mass of sputtered metal is given in terms of grams/ampere-hour.

(To be continued.)

BRITISH PATENT ABSTRACTS

557,389. Application: 24.3.43. **Treatment of paper.** Tootal Broadhurst Lee and Co., Ltd. This invention deals with increasing resistance of paper to swelling in the presence of water vapour, water and other swelling agents and consists in bringing sheets of paper into contact with an excess of a solution containing a small proportion of an acid or potential acid and a large proportion of a reactive aldehyde. Excess of solution is removed and the impregnated paper dried and subsequently heated for a short time at a temperature above 100 degrees C. Ammonium chloride and formaldehyde are given as examples of the materials used.

558,556. Application: 1.1.44. **Manufacture of New Condensation Products.** Society of Chemical Industry, Basle. A resinous compound containing at least one carboxylic acid halide is treated with formaldehyde and a hydrogen halide so as to produce a water soluble cation-active product especially suitable for increasing the resistance to " slip " of artificial silk fabrics.

558,654. Application: 17.4.41. **Improvements in and Relating to Production of Modified Phenol - Aldehyde Resinous Condensates and Compositions Comprising said Condensates.** British Thomson-Houston Co., Ltd. A modified phenol-aldehyde resin is prepared in two stages, the first comprising the forming of a solution of dispersion of Vinsol and a phenol in the proportions of about 5:1 and reacting the solution under acid conditions with less than one molecule aldehyde per mol. phenol, and the second stage comprising introducing sufficient additional aldehyde to obtain a mol, ratio of total aldehyde to phenol greater than 1:1 and continuing the reaction under alkaline conditions.

558,955. Application: 27.6.42. **Improvements Relating to Art of Uniting Surfaces of Wood or like Materials and to Compositions Suitable for use therein.** R. P. Roberts and K. Jones. Process for bonding together surfaces of material composed substantially of cellulose, comprising the application of a composition containing polyvinyl alcohol and aldehyde and a catalyst for acetalizing the alcohol by the aldehyde and pressing the surfaces together.

558,987. Application: 16.6.42. **Improvements Relating to Processes for Production of Oxy-Benzyl-Mono-Alcohols by Condensation of Phenols with Formaldehyde.** Max Koebner. The production of oxy-benzyl-mono-alcohols by condensing of phenols having more than one replaceable atom in the molecule, with formaldehyde in the presence of an alkaline catalyst, the ratio of phenol to formaldehyde being not less than 5:1.

Coal in Relation to Plastics
(Contd.)

By H. RONALD FLECK, M.Sc., F.I.C.

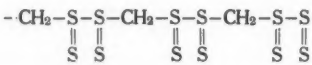
A broad canvas on which is drawn the vast array of plastics and chemicals that are being or can be made from coal, which must be our main raw material for many years to come.

Thiokols. The thiokols are members of a family of synthetic elastomers termed the thioplasts. These substances are of considerable interest since they contain sulphur and resemble to some extent vulcanized natural rubber. They were discovered by the American chemist, Patrick, by one of those fortunate accidents which lend a spice of adventure to research work. Patrick was endeavouring to find a new anti-freeze liquid and obtained instead a rubber-like solid which was later christened Thiokol and patented in 1932.

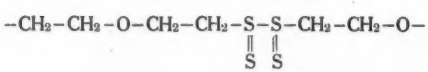
The preparation of the Thiokols from simple substances is exemplified by the following details:—A controlled solution of sodium tetra-sulphide is pumped into a reaction vessel, ethylene dichloride added and the mixture heated with vigorous stirring. A white latex results in an hour or two and this is coagulated by the addition of acid, the concentration, rate of addition and speed of stirring being carefully regulated in order to obtain a granular product. The granules are well washed, filtered, dried and finally pressed into blocks for transit.

Thiokol A has a pungent lachrymal odour, possibly due to the presence of co-ordinately linked sulphur atoms in the molecule. Thiokol B also possesses this type of structure but contains oxygen linked into the polymer chain. This latter substance is produced by the interaction of $\beta\beta^1$-dichloro-diethyl ether and sodium tetra-sulphide.

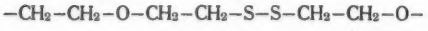
Thiokol D is made from Thiokol B by removal of the co-ordinately linked



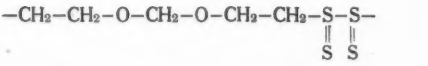
THIOKOL A.



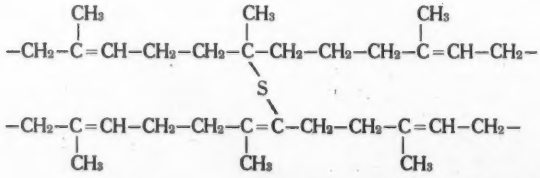
THIOKOL B.



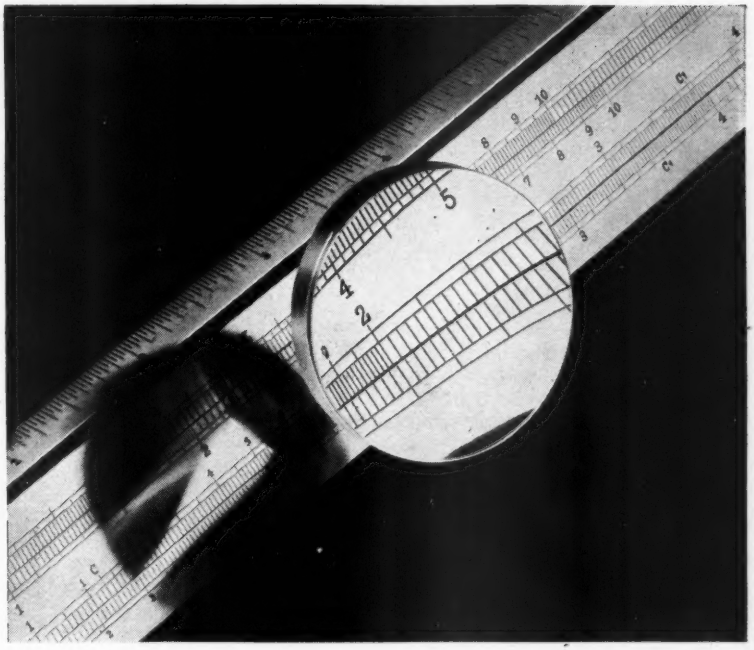
THIOKOL D.



THIOKOL F.



VULCANIZED NATURAL RUBBER.



OPTICAL RESINS

Two types of plastics are produced by I.C.I. in a special quality for optical work. They are unplasticised polymethyl methacrylate (known as "Transpex" 1), which is equivalent to optical Crown Glass, and unplasticised polystyrene (known as "Transpex" 2), equivalent to optical Flint Glass.

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sulphur atoms with 40 per cent. aqueous caustic soda solution.

Thiokol F is an exceedingly valuable thioplast having no odour and extremely high resistance to solvents such as aviation petrol and benzole. The starting point in the synthesis of Thiokol F is ethylene chlorohydrin which is converted to dichloro-ethyl formal and reacted with sodium tetra-sulphide.

The formulæ proposed for the Thiokols are shown on the previous page, with vulcanized rubber for comparison.

An interesting possibility for producing thioplasts from poison gas is foreshadowed by the recent patent granted for a process utilizing mustard gas ($\beta\beta^1$-dichloro-diethyl sulphide) and sodium tetra-sulphide. The product is a rubbery solid and presumably, by analogy, would have the structure shown below:—

$$-CH_2-CH_2-S-CH_2-CH_2-\underset{\underset{S}{\|}}{S}-\underset{\underset{S}{\|}}{S}-CH_2-CH_2-S-$$

This presumably is capable of modification by removal of the co-ordinately linked sulphur with 40 per cent. caustic soda. Since a prudent Government has almost certainly produced vast quantities of mustard gas against eventualities, it would appear that the raw material should be readily available in the immediate post-war period and should remove the embarrassment of large quantities of unwanted poison gas.

To return to our thioplasts as at present known. How can they be produced from coal? The chart (Fig. 2) shows that Thiokols A and B can be obtained via ethylene dichloride and ethylene chlorohydrin respectively. This statement is equally true for Thiokol D (action of caustic soda on Thiokol B) and Thiokol F from dichloro-ethyl formal via ethylene chlorohydrin. We require for these three materials ethylene and we desire to produce it from coal.

Coal-gas contains a small percentage (about 6 per cent.) of ethylene in gaseous form and it might be possible to increase this percentage by careful pyrolysis of the coal or by improved methods of separation (possibly by bubbling the gas through hypochlorous acid to form ethylene chlorohydrin).

There are, however, two or three feasible methods of producing ethylene from coal in good yields and of fair quality. They are (a) preparation of acetylene from calcium carbide and the formation of copper acetylide by passing the gas through ammoniacal copper-sulphate solution. Reduction of copper acetylide with zinc dust and ammonia gives ethylene, the copper recombining to form ammoniacal copper solution. (b) Acetylene combines directly with nascent hydrogen in the presence of finely divided nickel to form ethylene and ethane. This mixture will give ethylene chlorohydrin if bubbled through an aqueous hypochlorous acid solution, ethane being unaffected; by passing the mixture through a tower containing chlorine gas ethylene dichloride is formed, ethane being unaffected if sunlight is excluded from the reaction chamber. (c) Acetylene forms acetaldehyde readily, the latter is easily oxidized to ethyl alcohol from which ethylene may be produced continuously by heating with sulphuric or phosphoric acids.

Ethylene chlorohydrin combines with ethylene and chlorine to form $\beta\beta^1$-dichloro-diethyl ether.

The properties of the thioplasts are unique amongst the synthetic elastomers since they have remarkable resistance to many types of organic solvents, particularly the lower aliphatic hydrocarbons. They have excellent ageing characteristics and are very resistant to cracking and disintegration under exposure to oxygen and ozone. Although tensile strengths are low the thioplasts can be successfully compounded with natural rubber to which their own very valuable properties are imparted. It is probable that the thioplasts would be the most valuable elastomers to manufacture from coal in this country.

The chart in Fig. 1 shows that a multitude of plastics can be derived from coal utilizing the normal methods of chemical synthesis. Melamine resins,

acrylates, methacrylates, polyvinyl formal, acetal and butyral, polyvinyl alcohol and its esters, the acids necessary for esterifying and etherifying cellulose cyclopentadiene and naphthalene resins, polystyrene, glyptals, nylon, phenolic and cresylic resins, toluene sulphonamide resins, urea and urea resins, maleic anhydride and its adducts, coumarone and indene resins and formaldehyde. This bewildering number of plastic materials are all derived from coke, coal tar, light oil, and water gas. Coal therefore deserves all the attention that we as a nation can bestow upon it; we must husband our resources.

Let us see how the main classes of raw materials recorded above are produced from coal. Since formaldehyde is such a ubiquitous material in our industry we will give it pride of place in this discussion.

Formaldehyde. The water gas produced by passing steam over red-hot coke is heated under a pressure of 500 atmospheres with hydrogen to a temperature of 400 degrees C., using a catalyst, usually zinc oxide. The liquid produced is methanol or methyl alcohol in 80 per cent. yield. The vapour of methyl alcohol mixed with air is passed over spirals of heated copper or over heated platinum asbestos, the formaldehyde thus produced forming an aqueous solution containing about 40 per cent. of the aldehyde. Formaldehyde produced in this way will easily be sufficient to give all that the plastics industry can possibly want. One ton of coal will yield about 300 gallons of 40 per cent. formaldehyde solution at a fairly low cost. By evaporating formaldehyde solution a white solid polymer is obtained. This solid is useful for resin reactions in non-aqueous solution.

Formamide. This liquid is a useful solvent and on dehydration yields anhydrous hydrocyanic acid which is used in producing polymethyl methacrylate. Formamide is made by distilling ammonium formate produced from formaldehyde by oxidation to formic acid and neutralizing with ammonia. It is therefore easily derived from coal.

Melamine. Until a few years ago this interesting chemical was a curiosity and was exceedingly expensive. Recently, plastic materials derived from melamine have been found to have very valuable properties which make them superior to many of the older plastics. Naturally, intensive research has been carried out on the quantity production and cheapening of melamine. It was discovered that coke was the best source material via calcium carbide to calcium cyanamide. When calcium cyanamide is boiled with water containing a little ammonia it is hydrolysed and rearranged to dicyanodiamide, a white crystalline solid which in turn forms melamine on heating at about 200 degrees C. The pyrolysis of dicyanodiamide to melamine is usually controlled by heating in a thermally buffered solvent or by fusion in the presence of a heat-stable salt such as guanidine hydrochloride. Ten tons of coal will yield about 2 tons of pure melamine, the process being relatively simple and inexpensive. Melamine has a cyclic ring structure containing three amino-groups and it reacts easily with formaldehyde to give a host of resins of various grades. These resins form the basis of stoving and air-drying enamels, moulding powders, water-proofing solutions and impregnating liquids. Melamine resins have an excellent future and in view of their formation from coal should be produced abundantly in this country, always provided that we set up a satisfactory carbide industry.

Coumarone and Indene are substances found in the solvent naphtha distillate of coal-tar. They can be polymerized in situ by treating the naphtha fraction with sulphuric acid, washing and subsequently removing the naphtha hydrocarbons by distillation. The yield from coal is small but adequate since the resins are of a specialized nature and are consumed in small amounts.

Naphthalene occurs in coal-tar, 10 tons of coal yielding about 60 lb. of this hydrocarbon. By treatment with sodium in alcohol and subsequent polymerization, hydro-naphthalene resins are produced. These resins are colourless and very hard

and are likely to be of use to the paint industry. Naphthalene reacts with formaldehyde in the presence of sulphuric acid to form hard, brittle resins which are soluble in paint solvents, and which form excellent varnishes when modified with drying oils. Probably the best use of naphthalene is in the manufacture of phthalic anhydride for the preparation of glyptal and alkyd resins for use in the paint trade. Naphthalene sulphonamide resins have also been produced but have not been widely used.

Nylon. During the past few years this plastic has become one of the foremost textile raw materials. Its synthesis and industrial production is one of the romances of chemistry. Wallace H. Carothers, the brilliant chemist who headed the team of workers who discovered neoprene, set out to produce synthetically a material which should have the chemical and physical properties of natural silk. Silk as it is obtained from the cocoon consists almost entirely of a protein substance named sericin. Abderhalden, a German chemist working with Emil Fischer, had shown that natural proteins were long-chain polymers linked together through amino-groups and he had succeeded in synthesizing a long-chain poly-peptide which had many of the properties of a natural protein. Carothers and his co-workers took this work of Abderhalden a stage farther and investigated the polymers obtained by esterifying amides with organic acids. Many trials were made, but the systematic programme had been magnificently organized and at last the research had a successful outcome. Polymer 66 was born, a poly-ester amide obtained by condensing hexa-methylene diamine and adipic acid together. This material was named nylon although this name has since come to mean a series of such polymers of like construction but differing in chemical entity. The work was pushed to its logical conclusion, the industrial manufacture of nylon yarn for textile weaving. Unfortunately at this stage Carothers died at the early age of 41. He was a brilliant chemist and his loss to the plastics industry is profound. Fortunately, he had trained a fine team of co-workers.

The value of nylon lies in the fact that it replaces natural silk and that it can be produced from coal. One of the main sources of natural silk is the Far East, mainly China and Japan, and this source is closed to us. The production of nylon has avoided a most acute embarrassment to the Allies, a shortage of silk.

The production of nylon is somewhat complex, but it is easily amenable to control at all stages of manufacture and it is now being produced in this country. The post-war production should be greatly expanded in order to render this country more or less independent of natural silk imports. We have the coal for nylon even if we have not the worms for silk.

The starting point in the synthesis is phenol. This is hydrogenated in the presence of a catalyst to cyclohexanol, the latter being oxidized with nitric acid to adipic acid. Adipic acid is converted into its diamide by treating the acid chloride with ammonia. Next, dehydration of the amide yields adiponitrile which on hydrogenation gives rise to hexa-methylene diamine. The diamine is condensed with adipic acid in xylene solution and held at a high temperature until test samples show that the polymerization has proceeded far enough.

Little need be said here of the preparation of phenolics, cresylic and urea-formaldehyde resins since their properties and method of manufacture are widely known.

In conclusion we must remember that petroleum, the greatest natural competitor to coal as a source of plastics, may be in danger of drying up. Calculations purport to show that the U.S.A. have only 15 years' supply of petroleum, whereas this country can continue mining coal at the present rate for another 150 years. It is certain that if we use our coal wisely, avoiding waste, this time limit can be usefully extended. General Smuts has said that Britain will finish this war poor in everything but reputation. Poor we may be, but we live above a treasure chest which we can unlock at will.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

GAUGE AND TOOL MAKERS' ASSOCIATION, LTD.—We have received the new edition of the Association's handbook containing the complete list of members. In a well-written preamble, the origin of the foundation of the Association is set out, together with a brief survey of its services. For further information readers should write to the secretary, Mr. Gilbert T. Beach, who is already so well known to members of the British Plastics Federation, at Standbrook House, Old Bond Street, London, W.1.

WAR DAMAGE ACT, BUSINESS SCHEME PREMIUM.—The Board of Trade has, with the approval of the Treasury, decided that in respect of the six months beginning April 1, 1944, and ending September 30, 1944, the rate of premium payable under any policy issued under the Business Scheme shall continue to be at the rate of 5s. per cent.

PRODUCTION BULLETIN. — The February, 1944, issue of this bulletin contains many interesting features for the factory, including Group Control Charts (third of a series of practical applications of quality control); Crush Dressing for Grinding Wheels; Servicing Employees' Micrometers (a Joint Production Committee suggestion for reducing avoidable scrap); Music in Working Hours (a survey of American practice); and an interesting description of War Production in a Small Country Town. Finally, there is a useful note on the repairing of heavy motor vehicles.

SOCIETY MEETINGS

I.P.I. Southern Section Activities.—Saturday, February 5. A joint meeting was held with the Hampshire branch of the Institute of the Electrical Engineers at Kimbells's Café, Southsea. Before an audience of 150 people, Dr. Harry Barron, F.I.C., gave a talk on "Plastics in the Electrical Industry."

Wednesday, February 16. Mr. G. L. Barron gave a talk on "Plastics" at a Fleet Air Arm Station in the South of England.

Wednesday, February 23. A film show was given to members of the Southern Section at the Polygon Hotel, Southampton. Dr. Harry Barron, F.I.C., was in the chair and acted as commentator.

Society of Chemical Industry (Plastics Group).—On March 20, at University College, Nottingham, Mr. G. Loasby will read a paper on "Nylon."

MR. H. W. ROWELL, M.I.Chem.E., who is well known as an author and consultant in the plastics industry, has been awarded the Hinchley Medal by The British Association of Chemists.

OBITUARY

We regret to announce the deaths by enemy action of Mr. and Mrs. A. J. A. Wallace Barr.

Mr. Wallace Barr, who was so well known and so popular to thousands in the aircraft and lacquer industries, founded the first Cellon Company in 1913, mainly as a result of his general interest in aviation matters, which he had followed as a hobby since early 1911. From this small start developed the present company, Cellon Limited, of which he had been chairman and managing director throughout.

Mr. Wallace Barr was pre-eminently associated with all the progress which has been made on protective coverings for aircraft, being associated with this project during the 1914-1918 war, the intervening period of aircraft development between the wars, and in the requirements for the huge development which has occurred in the present war.

In regard to aviation generally, Mr. Wallace Barr was a member of the Royal Aero Club, and served on the committee of the Club for a very long period. He also attended or served on the organizing committees for all the important aviation events which have taken place in this country. He attended the Schneider Trophy contests at home and abroad, King's Cup races, the England-Australia race, and all events of a similar nature, in addition to which he served on several committees for the advancement of aviation.

Mr. Wallace Barr was held in high esteem by all interested in aviation from both sporting and commercial sides, as well as by his co-directors and all the employees of his company. Aviation and Cellon Limited have suffered an irreparable loss.

Designing for Plastic Moulding

By W. M. HALLIDAY

Continuing the discussion commenced in the February issue, a number of the more important Moulded-part Design features are here considered, in the light of their effects upon economical mould design and construction as well as general mouldability. Some practical difficulties are also illustrated, together with indications of the methods adopted to avoid disadvantageous design features, which are the chief cause of such difficulties encountered in moulding practice.

IN the first portion of this article attention was directed towards a number of essential considerations governing the economical design of a moulded article, with especial emphasis upon the desirability of the development of the design specifically for the plastic moulding process, rather than along the more usual lines of making the projected part a more or less faithful reproduction of some non-plastic component to be substituted, which would invariably have been designed for a vastly different method of manufacture from that of moulding.

It now remains to consider in closer detail a few of the chief points of moulding design, which it would appear do not generally receive the careful consideration they deserve, and which is certainly necessary if successful and economically sound moulded products are to be made. Particularly it is desirable that the user-manufacturer should be fully cognizant of all the influences concerning these points.

General Rules Affecting Moulding Component Design

Briefly there are four main rules amounting almost to the scale of general principles concerning moulded articles and mould designs which the prospective user as originator of the basic design features of any projected plastic moulding, would do well constantly to bear in mind. They are:—

(1) The external and internal shape of the moulded piece should be of such a configuration as will permit the ready opening and closure of mould blocks or press ram, in which the cavity and cores are contained. This holds true whether the part is to be made by either the compression or injection process, although in the former the free opening and operation of the press ram must also be duly considered and provisions accordingly made in designing the part.

(2) That design should preferably be selected which embodies an internal formation requiring the least complicated kind or number of core-forming members in the mould, in order to maintain the construction and operation of the latter in as simple a form as practicable. The corings embraced by a particular design should permit its ready removal from mould after completion of moulding cycle.

(3) The design should be one which will enable the mould cavities to be adequately fed, and air vented with sufficient capacity and speed to produce sound mouldings at an economical rate of output.

(4) The design and general strength characteristics to be possessed by the proposed moulding should permit of the use of the most economical and appropriate grade of powder or material. This point will involve close attention to many factors such as wall thickness, contour of same, extent and number of cored holes, insertion pieces to be moulded in, quantity of material to be required for a moulding and so on.

The mould for any component will essentially comprise at least two members, these being either rectangular or circular steel or alloy-steel blocks, each having approximately the same bulk and overall dimensions. During moulding they are clamped together and held there under great pressure simultaneously, with which is the application of considerable heat. In compression moulding the press

ram itself enters the cavity of mould blocks to form the internal shape of the part being made, the pressure, of course, being exerted by the ram at the same time.

After the moulding operation has been completed the mould blocks are opened, or press ram withdrawn, as the case may be, the lower block usually remaining stationary, whilst the ram moves upwards in a vertical direction a distance sufficient to ensure extraction of core members and ejection of the finished moulded article.

Following from this brief description of the mechanical functioning of the moulding process (in part only) it will at once be appreciated that in order to ensure smooth and free working of the mould blocks and their cores, etc., it will be necessary for them to be of the stiffest possible proportions so that they will be able to resist all tendencies to warp or distort under extremely great pressures and heat.

Therefore the design of the part should be such as will permit the use of the largest blocks possible, or not of such a degree of intricacy as will cause the mould blocks to be unduly weakened at some point in order to provide for necessary cavities, etc.

There is a further important consideration bearing upon this need for selection of amply strong mould blocks. This is care should be taken to secure blocks stiff enough to resist the great pressures and stresses imposed upon them whilst undergoing manufacture. The present writer has repeatedly had experience of moulded article designs of such a complexity of form or size which have resulted in grossly weakened mould blocks, such weakness only being fully appreciated when production begins.

In reference to the second rule stated above, it will be equally clear that the designed article should possess uniform internal shapes as far as possible, together with simple outline contours and cavity depth as shallow as possible, too. If these ends are overlooked and intricate or deep corings become necessary it may very well mean greatly increased mould manufacturing difficulties as well as added costs of both part and mould, because equally intricate core forming and withdrawing mechanisms will become necessary, which, of course, will be directly reflected in ultimate costs.

Effect of Mould Block Parting-line

It is generally considered good working practice in moulding and mould design either for compression or injection processes to arrange the parting-line surfaces of the composing mould blocks so that they lie at right-angles to the axis of the line of opening of blocks.

In addition, efforts are usually made to position the parting-line so that the unavoidable flash formation caused by this point comes upon a non-essential surface of the finished article, and also that the removal of such flash shall be in as simple a manner as possible.

Wherever practicable, the parting-line should lie in one plane only, as it is obvious flash-removing operations will be simplified.

The would-be user of the moulded article, when instituting design features, should realize that from the point of view of mould construction and their smooth operation also, single plane parting-line forms both the simplest, most inexpensive, and most economical practice.

Sometimes, however, the design is such as inevitably necessitates having the parting-line along an irregular path so that it shall conform to the largest area of the intended moulding. If this becomes necessary both mould construction and general production of parts may be fraught with special and, indeed, unusually difficult problems.

Sealing the Mould Blocks

For example, in the matter of mould construction the intimately contiguous parting-line surfaces of each mould block will have to be very effectively matched so as to seal properly to avoid an escape of material when the latter is subjected to pressure by press ram or injection plunger. If this is not accomplished efficiently, mouldings of incorrect shape or

dimensions will result, plus heavy flash formation, which, in turn, will entail additional labour and time in its removal. From the mechanical point of view, the mating together of two regular surfaces both in the same plane is infinitely more simple than a similar sealing of two faces following a broken or irregular shape in two or more planes.

Again, during actual operation of mould some objections to smooth working usually arise because of the tendency of small particles of plastic material left over from previous " shots " to adhere to parting-line surfaces of blocks. These must be scrupulously cleaned off otherwise the blocks cannot be closed with a perfect seal, and flash is increased, etc. With a flat, regular parting-line surface this task is simply and quickly performed, in contrast with the time and caution needed to clear irregular-shaped surfaces.

It is sometimes impossible to locate the parting-line surface of mould blocks at other than an inclination to the normal working axis of their line of closing and opening. But it should be remembered that several disadvantages are likely to be associated with such inclined parting-lines.

(a) Uneven pressure will be imposed upon the respective blocks or core members during the compression pressure stage. This will lead to the development of unequal side thrust on the respective blocks.

(b) In time, unless remedied, this may lead to permanent misalignment of mould blocks, or, at best, some interference with their normally smooth working, with resultant slowing down of production.

(c) It is almost certain to lead to an undue amount of maintenance attention being required to keep moulds in proper working condition.

Remembering the fundamental action of the moulding process, viz., the press ram moving vertically wherever possible, the design should allow for the parting-line to be remote from any point which will require strict alignment between press ram and the mould cavity, otherwise errors in sealing are likely to ensue due to misalignment of ram with platens.

The designer should avoid those configurations which make necessary an inclined or irregular parting-line in favour of the straight and normally situated one. If this is done as far as possible, not only will more satisfactory products be secured but, generally, mould construction and methods of manufacture will be appreciably simplified and cheapened, this obviously being reflected directly in costs and output.

Strengthening the Moulded Part by Ribs, Etc.

It is nearly always possible, and in many instances, indeed, desirable and preferable, in the interests of strength features, to provide supporting or stiffening ribs, beadings, projections, or bosses to a part in order to enhance its mechanical rigidity, stiffness and strength. Recourse to such features offer the designer a remedy against having to make the walls of the part too thick or reduced in length.

By a judicious disposition of such ribs, etc., in most cases, the appearance of the moulded part need not be impaired, even should it be impossible to locate them on other than an external surface, which, in fact, is very rare.

Ribs are valuable not only because they are a simple means for greatly improving the mechanical strength, but because they afford great assistance to the moulder in the following manner.

(d) They provide simple and inexpensive means for securing auxiliary and additional feeding of material into the cavities, or they assist better flow, filling of mould, and welding of material.

(e) By locating any such ribs in such a manner the unequal shrinkage of material may be considerably neutralized, thus avoiding unsightly " sink " marks and uneven surface finish. The moulder is enabled to strike a better balance between wall thickness, depth of cavity and flow conditions of material being used, thereby assisting towards the production of more satisfactory and sounder mouldings.

(f) Ribbing the moulded article will usually ensure that it can be ejected from mould blocks or stripped from core members with a minimum amount of distortion. This will give the moulder stricter control over essential dimensional accuracy, uniformity of contour, and surface finish which would not otherwise be accessible to him.

(g) Usually, an economy of material will also be derived from the use of ribs, beadings, etc., as the wall thickness may then be reduced in non-important points. Weight is saved and locations of article which are to be subjected to greater stress or pressures can be accordingly strengthened without incurring a general thickening up of component walls.

A word of caution is necessary in this respect, however; when incorporating ribs and the like into a mould design, care should be taken to fashion them in such a way as to ensure their being readily reproduced by ordinary manufacturing or machining processes, and, moreover, so that they can be easily moulded. Otherwise, the moulder may be caused increased worries and difficulties which may offset any gains likely to ensue from their application to design.

Wall Thickness

This is generally a very important aspect of the design of an article and will have to be determined comparatively early in design stages, especially where the part is required for electrical or insulation purposes, in which cases wall thickness is of prime importance.

No hard-and-fast rules conditioning dimensions can here be laid down as applying to every moulded article. Instead, it will be necessary for each individual case to be treated separately, its requirements, in this respect, being governed by the service conditions it will have to meet.

Correct wall thickness, together with true proportioning, is usually regulated by the mechanical or di-electric strengths demanded of the part. But it is also as well to remember that the moulding processes themselves involve restrictions beyond which it will not be practicable to go.

But, as a general guide, the minimum wall thickness should be used, the reasons being that the thinner the wall the shorter will be the curing time, and, therefore, the greater output, all other factors remaining equal, of course.

For the average boxlike component, such as is in wide use, a satisfactory workable mean, from the moulding angle that is, will be about .090 thick. On heavy or large articles wall thicknesses may usefully be increased up to $\frac{5}{16}$ in., and in some cases up to $\frac{3}{8}$ in. Rarely will it be found necessary and, indeed, practicable, as far as commercially economical production is concerned, to exceed this latter figure.

If the walls are made too thick the curing time required for completion of the article will be so greatly increased as to render economical manufacture difficult.

Should the required characteristics of the finished moulded article make necessary the selection of a fabric or impact type of material or, say, one of the resin-board or powder and fabric combinations, chosen to obtain added strength, very thin wall sections should be avoided. In these connections it will be inadvisable to make their thickness less than .050. This will be increasingly important if the walls of such components are to have openings, cored holes, recesses, or extensive gaps running along the side parallel with line of ram stroke or mould block opening.

In other cases a minimum wall thickness of .035 to .040 may safely be applied provided demands of mechanical strength permit.

Some caution is needed in determining this lest, for the sake of material economy, the part may be designed with insufficient wall thickness, leaving it too fragile to withstand the stresses of moulding, ejection from mould cores or press ram, and distortion due to cooling and shrinkage. If this is allowed to arise production delays will inevitably accrue with an increase in faulty parts, scrap mouldings, and an increased expenditure upon

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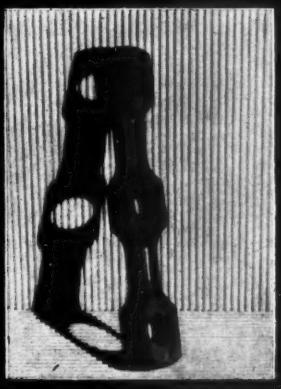

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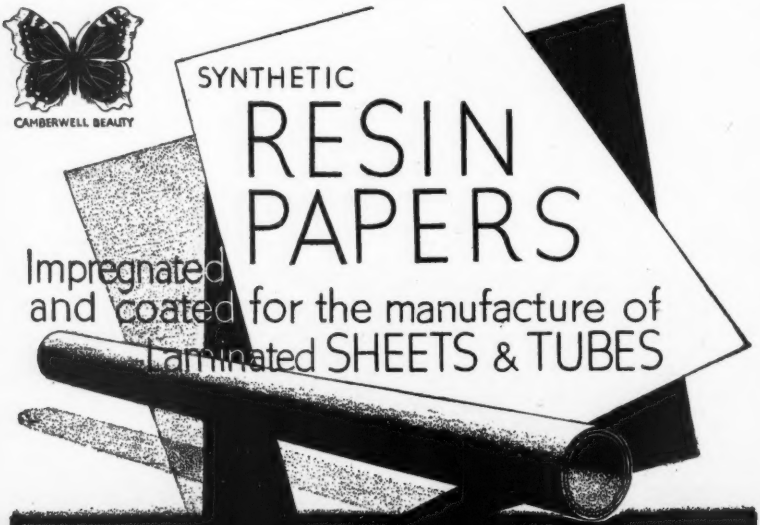

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corrective measures to reclaim faulty parts. There will also be some risk that a distorted moulded part may become jammed upon cores before its complete removal can be performed. In such instances it has been known that slender cores or important projections of mould cavities have been damaged due to the force needed to effect a clearage of the jammed article.

In general, then, sound design will aim at securing the minimum use of material, together with its best distribution, so as to impart adequate electrical or mechanical strength at all essential points of the article.

Before leaving this subject of wall thickness, it perhaps will be useful to mention that all external surfaces should be devoid of sharp edges or acutely pointed corners on all points except that of the parting-line. Such features tend not only to result in a mechanically weaker component, but also incur additional machining and manufacturing operations upon the mould, which may in some cases be considerably complicated.

Such sharp corners, too, have a tendency to slow down production by impeding the flow of material through the cavity, which, in its turn, will result in an imperfect welding of material at points remote from greatest pressure of ram, etc.

Much experience in the investigation of faults and their cause has shown that in the case of fractured mouldings, the line of break or crack very often originates at a sharp corner. It should be remembered that the revealing of such cracks may occur some time after the moulding has left the mould, indeed, when it is actually in service.

The remedy is, of course, to arrange the design so that all walls blend into as large a round as possible at the points of their juncture. Such rounds, of course, should be struck from true radii and preferably be of true arc shape and also correctly blending with wall surfaces. If awkward curves which are not correct arcs are stipulated the mould engineer may be confronted with some difficult problems of machining in order to reproduce such curves and, therefore, mould charges must be proportionately raised.

Uniform Cross-sectional Area of Walls

Allied very closely with the questions of suitable wall thickness is the connected subject of uniform cross-sectional area.

Sudden, extensive or awkwardly located discrepancies of wall area should always be avoided. Several very substantial practical benefits are to be derived from a more uniform sectioning of walls, chief of which are here noted for the guidance of designers.

(h) The finished moulded part will undergo a commensurate uniform rate of shrinkage, thus affording the moulder better control over important forms or vital dimensional tolerances.

(i) Uniform wall section tends to lessen the strains upon the finished part whilst it is being withdrawn from mould blocks or, later, when it is actually under working conditions or in storage.

(j) Improved surface appearance will result. Unequal cross sectional areas tend to cause marred surfaces on part due to "sinks" as a result of unequal curing times of adjacent thick and thin sections.

(k) Uniform sections will also promote the simplification of both mould design and constructions, as well as the method of its manufacture. This will be particularly the case with regard to moulds employed in the injection method.

(l) In the case of thermosetting materials an irregular cross-sectional area will increase the curing time, thereby reducing output. With thermoplastic materials the rate of cooling time of unequal sections will, of course, control the speed of production.

Economical Design Shape of Moulded Articles

In the accompanying illustrations Figs. 1 to 4 are shown some practical examples of numerous disadvantageous

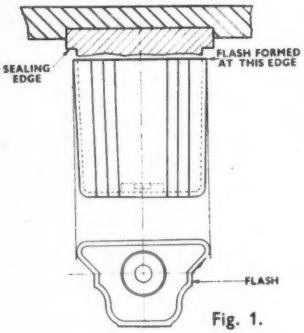


Fig. 1.

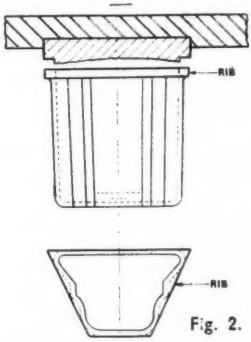


Fig. 2.

Figs. 1-4.—Examples of moulds with disadvantageous features and the suggested means of removing them.

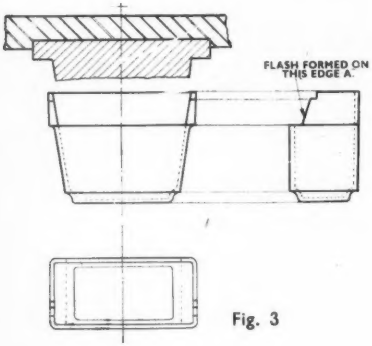


Fig. 3

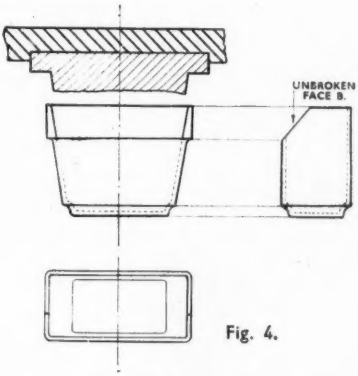


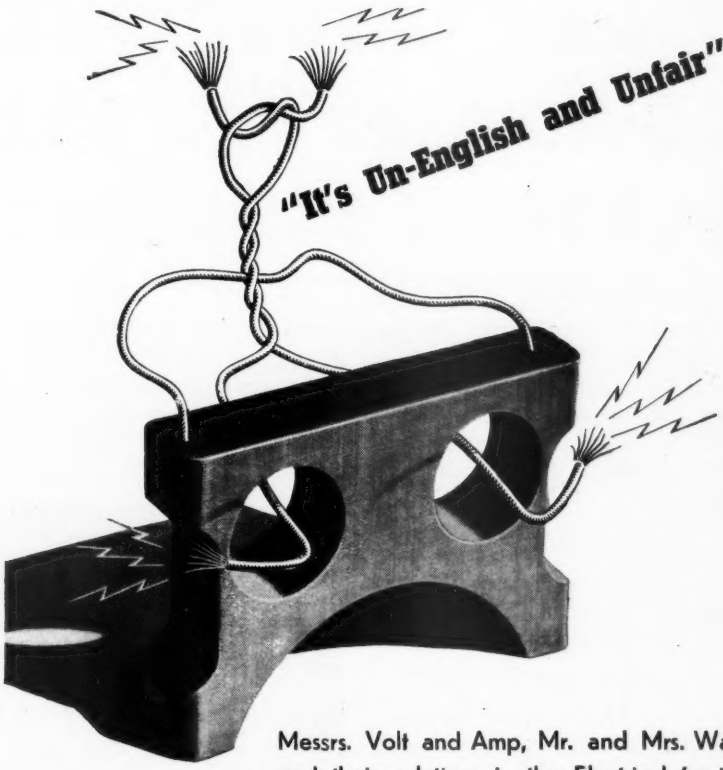
Fig. 4.

features which may be contained in a design of the simplest nature, together with indications of equally simple and inexpensive means for overcoming or avoiding such difficulties.

These examples are submitted in the hope that they may serve as pointers to improved design for the would-be user manufacturer of mouldings, offering suggestions of ways and means for avoiding such snags in any designs evolved by those who, whilst not specialist trained in such matters, desire to undertake the design and manufacture of simple forms of moulded articles.

Fig. 1, then, shows a plan and front elevation of a very simple type of box-like component, large numbers of which almost identically shaped articles are in extensive use. The lower view, looking on the top or mouth end of part, clearly indicates the contour followed by the front wall. As will be noted, the walls are fairly deep and both inside and outside are inclined to afford due " draught " so as to assist easy stripping from press ram.

The results of this design will be a moulding having a flash around the top edge, as is indicated in upper view. Removal of this flash will, in practice, present considerable difficulty, due to the need for the tool to follow the peculiarly wavy curved edges. Another method would be to remove an amount of material clean off top edge by grinding until flash disappears. This latter course



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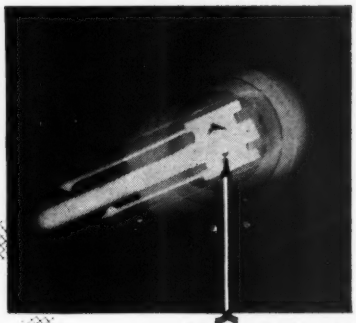

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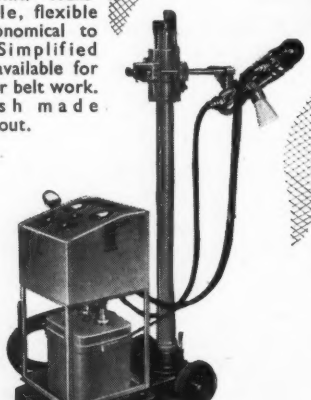

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will not prove satisfactory, however, for the following reason:—

Whilst it can be accomplished by a straightforward machining operation, such as grinding, it would not be reliable because the thickness of flash, and thus the amount of material to be removed from top of part, would not be uniform throughout the production of a batch. Thus some mouldings would be too short and others too long in over-all dimensions.

Fig. 2 shows a very simple manner in which the design could be modified to render such difficulties non-existent. If adopted, the design will then be such as to ensure that any flash formed will lie not on a very complex or multi-curved edge as previously was the case, but on three straight side flat edges. This is accomplished by forming a small beading around the top edge (see lower view in Fig. 2), which in effect imparts additional appearance qualities. The sides of this bead should, of course, span the crests of all the curves making up the wall shape as shown.

As will be appreciated, this modification to design involves but little extra cost or machining of the mould, which would be far more than offset and recovered by the savings effected in flash-removing operations. The article, too, is stiffer, less liable to distortion than would be the case with one according to the original design in Fig. 1.

The beading need not necessarily be a square one as here illustrated, but could be rounded providing its top edge was left flat. A semi-circular shaped beading would entail extra cutting and matching of mould blocks, and, of course, the formation of a flash line on the highest point, which would require removal.

Yet another common disadvantageous design feature is shown in Fig. 3, which example from the moulder's "case book" illustrates how very easy it is for the designer to create manufacturing, mould making, and product finishing snags.

Again, this is a box-like component. Its cavity opens out on to both the top and the upper portion of front side and at each end is stepped, as shown. This stepping is the cause of complications in the manufacture of the mould blocks, which have to be machined and fitted together in such a manner as will ensure a close seal throughout this stepped edge.

As a machining and fitting task this could no doubt be satisfactorily accomplished, provided the necessary expenditure of time and skilled labour were available, and also if costs permitted, which they rarely do! But if it were performed with satisfaction there would undoubtedly be some flash formed at this point, and there is almost certain to be trouble in removing such flash with speed and economy because of the nature of the stepped edge. During removal of the flash there would be a risk of the small middle step being disfigured and the original shape lost.

A simple and far less costly type of design is given in Fig. 4. There it will be noted the design has been adapted so that instead of the stepped side there is a straight one, but which follows an inclined path. This will create less trouble for the mould engineer in securing a sufficiently close mating of the mould blocks to give proper seal, whilst the resultant flash on moulded part may be removed with greater ease, speed and with less risk of deformation of the side as would formerly arise in previous design.

As already mentioned, there are many very similar designs where but a slight modification such as the kind here explained would suffice to bring the form of part more closely in line with moulding requirements, as well as securing a better shaped and more accurately well-finished component.

Undercuts and Recessing in the Moulded Article

When a product is to be made having undercut or recessed portions on its external walls, it very often requires manufacturing in a split-type mould. The results of this are usually an increased charge for the moulds, as they are much more com-

plex and difficult to manufacture. On the moulded article itself an additional flash line will be created coinciding with the line of split of mould blocks. This extra flash will, of course, involve additional labour and time for removing and might easily incur some marring of the surface finish of the finished article if it be not possible to locate same on a non-essential surface.

Furthermore, it will often be found that the moulded component is weakened along and surrounding this further flash line, which, if extensive, may lead to a failure of the part to withstand service conditions.

Production will also be correspondingly slowed, due to the increased time required to operate the mould each cycle. In a split-type mould, one or more mould members which combine to form the complete cavity, etc., will have to be operated in such a manner as to allow withdrawal of finished piece. This usually entails the complete removal of portions of the mould normally required for coring the undercut parts.

Further moulding difficulties will arise from the fact that such loose mould components when removed from the main body of mould will tend to cool down much more rapidly than the remaining bulk, with the result that when they are once again placed in position their comparatively low temperature will immediately serve to lower that of the main mould blocks. Thus extra time, effort and heat will have to be applied to restore the mould to working temperature. This can very materially reduce the rate of production unless special measures are taken.

There is yet another point to bear in mind in regard to the inclusion of undercut portions in an article. Usually, such features involve the provision of elaborate mechanisms on the mould blocks either for the automatic withdrawal of core members, or to ensure their correct location and lock, etc., in which circumstances the mould costs would, of course, have to be increased.

In Figs. 5 and 6 a very simple and common type of moulded article is shown. The first illustration indicates the original design possessing several indifferent features, and particularly one in connection with undercut portions. As will be seen, this is a sectioned illustration of a moulded cup-shaped component (A). Its main internal opening has slightly spherical walls causing the mouth diameter to be less than that measured about one-third of the way down the

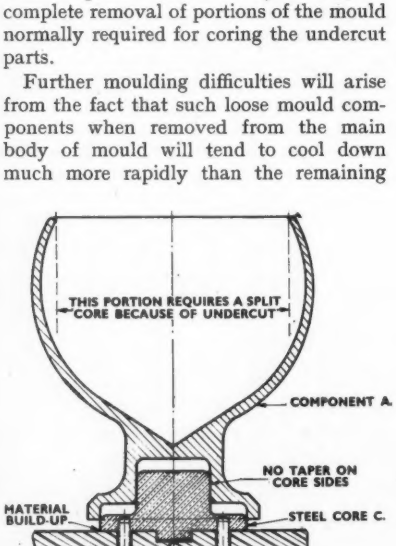

THIS PORTION REQUIRES A SPLIT CORE BECAUSE OF UNDERCUT
COMPONENT A.
NO TAPER ON CORE SIDES
MATERIAL BUILD-UP
STEEL CORE C.
CENTRALISING SPIGOT D

Fig. 5.—Moulded cup with undesirable features, e.g., undercut.

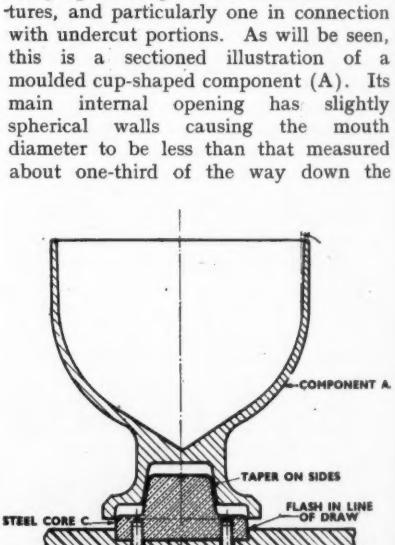


Fig. 6.—Here the design of the cup has been altered to eliminate the difficulties of undercut, etc.

bowl. Such a design would best be produced in a split mould, but would, however, embrace many of the aforementioned disadvantages.

In addition, it possesses other unsuitable features. For example, it is provided with a recessed portion at its base as well as a rounded-off rim.

The illustration in Fig. 5 also shows the method of fashioning this lower recess. The mould block (B) is equipped with a suitably shaped steel-core member as at C, this latter being securely fastened down to upper surface of mould block by means of countersunk head screws. There is a small centralizing spigot (D) employed for maintaining core (C) in correct position on block.

First, with this design there will be difficulty in removing such a part from any other type, but a split mould, owing to the lack of " draught," that is, side taper on the core member (C), as well as the overhanging formation of the cup bowl.

Incidentally, the method of fitting core (C) to mould block is not satisfactory because it will be extremely difficult to machine up and fit together these two mould members in such a way as to guarantee an absolutely sealed joint. And if such a joint is not made there will be the risk of flash formation. Material will also tend to build up underneath core (C). Such a building-up will again render extraction of finished cup moulding more difficult as the flash there formed will have to be severed before the article can be withdrawn from core (C).

This design also will give rise to manufacturing objections in respect of the radiused form of rim at mouth of cup. Additional troubles are likely to arise both in respect of mould construction and in removal of flash from this portion of component. The mould blocks will have to be so arranged that a portion of this radius is formed in one block, and a matching portion formed in the opposite block. The flash then would be difficult to remove without impairing the smoothness and curvature of the rim.

A very considerably improved design is shown in Fig. 6. Here it will be observed the main opening of the cup is not made spherical, but has the largest diameter at the extreme rim, the internal walls being thus inclined slightly to approach one another at bottom of bowl. The angle of inclination is approximately 3 degrees, which was found ample to ensure ready stripping from press ram.

To avoid the troubles connected with the forming of flash at recessed portion of base, as already mentioned in reference to previous design, it will be noted that the core (C) is actually seated into a suitable circular recess in top of mould block (B), this serving to align it correctly. Any flash formed in the joint line between these two members will then not cause any obstacles in the way of removing cup from core, because it will lie at right angles to the top face of mould block and in line with the direction of opening movement of mould blocks. There will be no necessity to sever this flash should it be formed each time blocks are opened.

In actual practice it was found that the mould cost was very much less than that which would have been necessary with the first design of cup, because a split mould would then have been required.

The flash was speedily removed from rim, too, because of a slight alteration in the shape of that portion. Instead of being semicircular it was made flat topped and a slight bevel on outside.

This indicates a comparatively simple modification of a design to enable it the better to fit in with best mould making and moulding practice, which resulted in an equally sound and satisfactory article as well as a much cheaper charge for tools, etc.

A somewhat more complicated problem is illustrated diagrammatically in Figs. 7 and 8, the solution of which will, perhaps, present several interesting points for the intending designer and user-manufacturer of mouldings.

Referring to the plan and front elevational views shown in Fig. 7, A is a box-like component in the left-hand end wall, of which there is a deep recessed or undercut portion (B), the inner wall having the

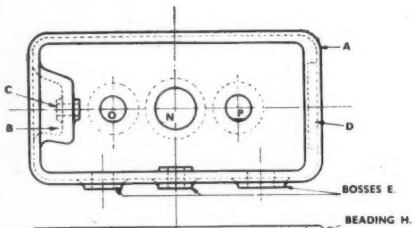


Fig. 7.—A complicated box-like moulding with manufacturing difficulties—

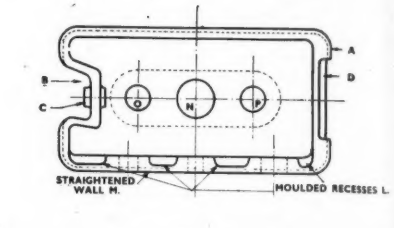


Fig. 8.—which have been eliminated by redesign while retaining essentials.

boss (C), through which a horizontal hole is to pass for the admission of a spindle to the mechanism to be installed inside the box.

Another rather shallow undercut portion is provided in right-hand end wall as at D. The front side is provided on its outside surface with five circular bosses (E) surrounding the holes (J), which latter pass clean into interior of box.

On the base are three more circular raised bosses (F) surrounding the three holes (N, O, P) in that portion.

The top rim of box is provided with a raised beading (H), this being of a true radius, but extending for practically half circle as shown.

Another very awkwardly shaped and disposed undercut is indicated in left hand at G (see lower view).

Altogether this design, which, by the way, faithfully resembles the shape of a cast-brass component to be replaced by a moulded one, gave rise to a number of difficulties, and is, in fact, a good illustration of the manufacturing snags which may be caused by unrelated design features to mouldability.

Examination of this design project just prior to designing of the moulds revealed no other valid reason for adhering to this particular shape, involving the three undercut portions, except the need for it to match up reasonably even with another component whose base portion was extended so as to form a cover for the box (A).

In Fig. 8 is shown the same part as redesigned, so as to bring it into closer conformity with best moulding practice. This redesign was effected by the moulding engineer after consultation with the potential user.

As will be specially noted, the two end undercuts (B and D respectively) are extended upwards to the extreme top of box, as shown. The purpose of this extension was to allow the necessary coring block to be attached to the press ram, and withdrawn from finished component by the normal vertical movement of the latter. In this manner the recessed portions were readily formed without trouble, without recourse to complex split-type moulds.

The horizontal hole in boss (C) was omitted, it being found more economical to arrange for a simple drilling jig to enable this hole to be accurately positioned and jig drilled after moulding.

The holes (J) in front wall were also omitted and later drilled in same manner.

The external bosses (E) around each hole on outside of front wall were also substituted for the continuous side of wall, as shown at M, with the bosses being formed internally in the following interesting manner in order to maintain length of hole to support spindles passing into interior of box.

The inside face of front wall was provided with four vertically disposed recesses at convenient intervals along its length, as indicated plainly at L; see upper view in Fig. 8. These recesses extend from extreme mouth of box to a point well below their respective holes, as shown in heavy broken line in lower view.

It will be observed that an ample taper is provided on the sides of these recesses, they being necessary to allow for ready withdrawal of core-forming members.

Here, again, by this means it was possible to provide the requisite coring members so that they travelled in a vertical direction in line of opening of mould blocks.

The awkward undercut (G) in the first example was eliminated altogether by means of a slight thickening up of entire side wall surrounding the recess (D), whilst the three holes (N, O, P) in the base were moulded in and the three bosses (F) combined to form a long surrounding stiffening panel (K). Here, again, a noticeable and time-saving simplification of mould construction was effected.

Another minor yet useful alteration lay in the shape of the appearance beading around the top edge as at H. Instead of this being almost semicircular in shape it was made only quarter circle, blending out smoothly with the vertical side wall, as shown, but presenting a perfectly flat surface to top of box. The value of this modification is that it permits the removal of flash at this point to be carried out with greater ease and speed, it simply consisting of a straightforward finishing operation of a sander belt, whereas with the original shape of beading some of the beading might be destroyed by removal of flash which forms at the crest of the curved bead.

It should not be interpreted from the foregoing remarks that split moulds and other kindred mechanical measures for facilitating the moulding of undercuts and recesses are not practicable and quite feasible. This would be erroneous, as there is a large number of such moulds in constant and widespread use producing important and valuable moulded articles.

But moulds designed and constructed on these lines usually are far more expensive to produce, much slower in operation and less reliable to operate, and generally give rise to increased maintenance attention and the need for greater care in their use.

Wherever possible, therefore, the far-seeing moulding designer will strive to evolve those designs which do not entail split-type moulds and so avoid the disadvantages undoubtedly associated with their use.

Taper on Side Walls and Core Members

When laying down a design of a projected component, attention should be devoted to the matter of taper on walls and core forming parts of mould to fashion the internal cavities required. Generally it will be advisable to allow the moulder the greatest latitude possible in this respect, with a basic minimum of, say, one-third degree.

Before the exact amount of wall inclination or "draught" can be settled, however, one or two other questions will have to be considered and suitably answered. For instance, it will be necessary to decide upon the type or method of ejection. In the case of the cup and box components already dealt with, ejection is by means of stripping the finished part from the press ram. With this kind of ejection it is essential that the taper be formed on the external sides of the part, that is on the surfaces immediately in contact with the mould cavity. Thus ready withdrawal from the cavity can be obtained and a portion of the up-stroke of the press ram is then utilized to effect ejection by stripping of the finished moulding therefrom by causing it to strike against a stationary stripper block at a certain

stage in its travel upwards with the ram.

If the design is such that the part will have to be ejected by means of knock-out rods or an ejector plate or ring, interjected into the mould block cavity after the article has been cured, then it will be necessary to provide the inclination on inside surfaces of component walls so that all tendency to move upwards with the withdrawing press ram is obviated.

Generally, it is not necessary to provide taper on both sides of the wall unless it is required to mould an article with an extremely deep cavity, when, in such instances, the part will have to be stripped from the press ram. This type is shown in Figs. 7 and 8, as the internal cavity of box A is both deep and wide and very large in proportion to the overall dimensions of the box itself.

Another important reason for making both the outside and inside of component walls tapered is that it enables a uniform thickness of wall to be maintained, which is very advisable in the case of large hollow parts or those having deep cavity formations.

The reason for maintaining uniform wall thickness on such parts is due to the rapid shrinkage which occurs when the mould is opened and the ram rises, bringing with it the hot moulded article, which latter, of course, immediately it contacts the cooler surrounding atmosphere, will rapidly begin to cool off and shrink. This shrinkage will be sufficient in extent and speed as to enable the component to get a very powerful grip on the ram, so that when it is eventually removed, often only by the application of considerable force, it will be found to have become very greatly distorted or even cracked at various points. The more even the wall thickness and the more side taper furnished the less risk there will be of unequal rates of shrinkage being caused and consequent cracking or warpage.

Exact amount of wall inclination will, however, be determined to a large extent by the grade of material to be used, the depth of internal cavities as well as wall thickness. It does vary a good deal with different grades of powder or material, but good working practice stipulates a minimum of 3 degrees. Difficult configuration of a piece having features which will obviously be difficult to mould and will tend to arrest free flow of material will require more wall draught than a simply shaped part.

(To be continued)

Letter from China

It is not often that we are thrilled by commercial letters, but we have received the following from Chungking, that amazing capital of a wonderful people. Best wishes to Sun Way and everybody in Chungking.

Sir,—We take the liberty of soliciting your assistance in connection with possible post-war exports of new plastic products, especially for the building industry. We would like our name placed before any such manufacturers in England who are likely to be interested in exporting to China later.

It seems to us that exports will play an important role in your country's post-war economy, and plastic products should prove to be a useful item in China, where economic development is still in its preliminary stages. However, we have to admit that our knowledge of the uses and potentialities of plastic materials is rather limited, and we would require to be given at least the elementary facts about them. We operate a real estate department, which in normal times also undertakes the designing and construction of buildings and, as we believe these activities will be resumed later on a much wider scale in collaboration with other builders, there should be a good opportunity for us to consider the application of the various products of the plastics industry. We trust the interested manufacturers will co-operate by keeping us fully informed of their products which will be available.

We suggest that you apply to the Department of Overseas Trade in London for information concerning us, and we believe The Chartered Bank of India, Australia and China in London can also supply you with essential data.

Shensi Road, Chungking. SUN WAY AND CO.

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XXIII.—Coating Media on Vinyl Acetate and Polyvinyl Alcohol Base (Contd.)

Polyvinyl Alcohol

In the study of the structure of the vinyl acetate polymers two groups of workers were engaged. On the one side Herrmann and Haehnel[355] and, on the other, Staudinger, Frey and Stark.[356]

Herrmann and Haehnel, by subjecting an alcoholic solution of vinyl acetate polymers to the action of an acid or alcoholic alkali, have obtained an insoluble precipitate, which after purification had the constitution $(CH_2—CHOH)_n$, i.e., polyvinyl alcohol. In determining the molecular weight they obtained the number 868, which corresponded to the polymer $(—CH_2—CHOH—)_{20}$. Owing to the insolubility in alcohol, the polyvinyl alcohol is easily purified by dissolving in water and precipitating this solution by alcohol. On saponifying with alkali, the polyvinyl alcohol frequently falls in the shape of flakes and fibres, strongly retaining alkali, and with water gives colloidal solutions, which can be liberated from the mineral part by means of dialysis. The polyvinyl alcohol is insoluble in most of the ordinary organic solvents. In glycerine and glycol, on heating, it gives a colloidal solution, which after cooling gelates. This body represents the reversible colloid, similar to haemoglobin, globulin, albumin and dextrin, namely, hydrosol, almost insoluble in any media, except water. In contrast with gelatine, the polyvinyl alcohol swells in water only slightly, going into the solution already in the cold and forming solutions immune to moulds. On cooling, these solutions do not gelate. The polyvinyl alcohol may serve as a protective colloid. In aqueous solution it can be acted upon by chlorine and bromine, but this action was investigated inadequately. On being treated by iodine and K_2CO_3 it yields, like in the case of acetaldehyde, iodoform. In the reactions with higher alcohols it forms acetal with benzoyl aldehyde. It does not react with lignin, but reveals the reaction ability towards hydrocarbons: thymol, menthol, indol and oil of minth.[357] By heating with the acetic anhydride and the anhydrous sodium acetochloride, it may be transformed into the initial polymerized vinyl acetate. Besides this, Herrmann and Haehnel obtained from it the ethers of the crotone, oleic, aleiritine, trioxistearic, glycol, and benzoic acids. With the caustic soda and carbon sulphide it forms xanthogenate.

The close relation of polyvinyl alcohol with hydrocarbons follows also from its ability to form with formaldehyde the combination which is related to amyloform of the starch, odourless, with the elastic property somewhat higher than that of amyloform. Like the latter, it is insoluble in water, but does not swell. It is more stable to the action of the temperature than that of amyloform, and fusible. Its diluted acids and alkalis slowly split off formaldehyde. The polyvinyl alcohol can be vulcanized by means of sulphur.[358] By vulcanizing it with the aid of the solution of sulphur chloride in carbon sulphide, i.e., in the process of cold vulcanization, it forms elastic products. By means of hot vulcanization with sulphur there is obtained the solid-jet-black products, which are well suited for the mechanical and other technical treatment. The duration of the vulcani-

zation procedure may be shortened by the application of accelerators.

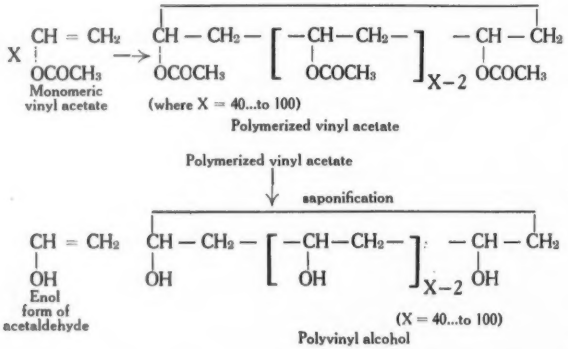
According to Herrmann and Haehnel, the polyvinyl alcohol must occupy the intermediate position between the sugar and the starch.

Analogy Between Polyvinyl Alcohol and Starch

A further analogy between the polyvinyl alcohol and the starch was indicated by Staudinger and his co-workers. He found that the lower the temperature at which took place the polymerization of vinyl acetate, the more viscous the resultant resins, which in this case contain polymers with a larger number of monomeric molecules than the products derived at a higher temperature. The latter substances are brittle. The former give more viscous solutions than the latter. By means of fractional precipitation from solutions the polymers of vinyl acetate may be separated into fractions having different degrees of polymerization, of which the less soluble are found to possess a higher average molecular weight and exhibit in solutions a greater viscosity than the fractions more soluble. Staudinger[359] was able to separate one compound, with the mean molecular weight 5,500, through fractional precipitation from the benzene solution by the petroleum ether into three fractions with the average molecular weights, 3,000, 4,500 and 9,000, which in the solutions of the identical concentration displayed a considerable difference in viscosity. Polyvinyl alcohol, just as starch, is colloidally soluble in water, and is not amenable to the dialysis. It can be released from aqueous solution by the addition of alcohol or acetone as white or yellowish flakes, similar in appearance to that of crude cellulose.

By the evaporating of concentrated water solution of this alcohol (pure) from the glass plate it is possible to form a transparent, water-soluble film. The decrease of viscosity of the solutions formed by the less polymerized molecules of the vinyl acetate is also observed in the solutions of the corresponding polyvinyl alcohols derivable from the former through saponification. With the saturated solutions of salts the solutions of polyvinyl alcohol release flakes in which salts are, apparently, included in the absorbed state. According to Staudinger, the polymerized vinyl acetate should be composed of from 40 to 100 molecules of monomer, which are found not in the form of the associated relatively simple molecules, but are combined with one another by the chemical bond.

(I)



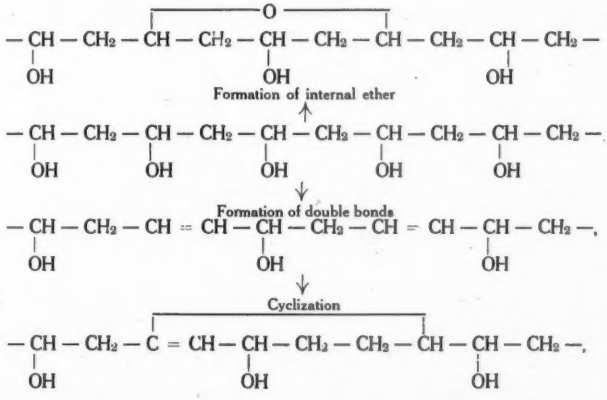
Staudinger is uncertain regarding the question as to the manner in which are saturated the terminal valances, and he also admits the formation of a high molecular ring. Besides this, in the opinion of Staudinger, there may be another type

(II) ...—CH(OCOCH₃)—CH₂—CH₂—CH(OCOCH₃)— —CH(OCOCH₃)—CH₂—CH₂—CH(OCOCH₃)—...

of polymerization (II), having a different order of bonding monomers.

Through oxidation of polyvinyl alcohol by concentrated nitric acid, Staudinger obtained oxalic acid and accords the preference to the formula (I).

By acetylation of water-soluble starch there is obtained the acetate, which is insoluble in water, but soluble in the organic solvents. The same is observed in the case of polyvinyl alcohol, and the colloidal nature of the substances here is not altered. Staudinger made an interesting attempt to convert by acetylation the polyvinyl alcohol of definite average molecular weight, derived from the polymerized vinyl acetate, back again into the latter with the same average molecular weight. It has been found, however, that the reverse acetylation cannot be attained completely, and Staudinger in this case admits a number of reactions taking place within the molecule:



Finally, there may occur the incomplete esterification. Of the other ethers, an interesting one proved to be the methyl ether, which, like methyl ether of starch, is soluble in water and alcohol. In addition to the above, Staudinger also derived the ethers of benzoic and nitric acids. Besides these analogies of polyvinyl alcohol with starch, there is also a common reaction with regard to iodine. In contradistinction to starch, the polyvinyl alcohol gives a blue colour reaction with the iodine solution in the potassium iodide only in strong concentrations. On heating, this coloration vanishes and reappears again on cooling.

However, there is also a drastic distinction between these compounds. Whereas the polyvinyl alcohol is stable, the starch is easily decomposed into glucose or its derivatives, which, according to Staudinger, indicates that indiscrete starch molecules, the anhydride glucose groups, are combined very weakly.

Through the reduction of polyvinyl alcohol by hydrogen iodide, Staudinger has obtained a high molecular, black, tar-like product, which, in his view, was not a simple paraffin hydrocarbon, but probably of a ring structure.

By reducing the polymerized vinyl bromide by hydrogen iodide under different conditions, Lvoff[360] obtained a compound, having fusion temperature 95 degrees C., slightly soluble in ether and completely insoluble in alcohol. Staudinger's product was also insoluble

in alcohol but soluble in benzene and chloroform.

Since polyvinyl alcohol may be regarded as polymer of vinyl alcohol, isomeric with the acetaldehyde, it induced Staudinger to make an attempt to ascertain the possibility of preparing this alcohol from acetaldehyde, but without success. Nevertheless, among the products alkalidensified acetaldehyde, Staudinger has revealed a negligible amount of polyvinyl alcohol.

It should be noted, moreover, that polyvinyl alcohol has much in common with starch with regard to its food properties, in consequence of which acetylene acquires a great significance, not only as a source of light, technical fuel, and the raw material for the synthetic chemistry of non-nutrients, but as the base for synthesis of nutritives.

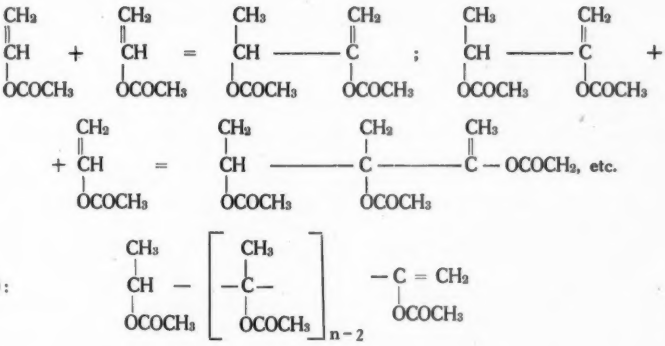
Prepared by Ruschinsky, according to Staudinger's data (by saponifying vinyl acetate in the solution of methyl alcohol by means of sodium methylate in the same solution), polyvinyl alcohol was released in the form of flakes; after the drying it had much contracted in volume, cracked, and the resultant product represented crusty fragments, whose surface was of brownish colour, yielding an alkaline reaction in aqueous solution. After purification by dissolving in water and precipitating with alcohol, there was formed an amorphous body of a slight yellowish tinge, which still was giving in aqueous solution a feeble alkaline reaction. This product without purifying by means of dialysis yielded a blue colour reaction with the solution of iodine in potassium iodide. The saponification process is, apparently, very complicated. Staudinger is of the opinion that at first there is formed the acetic ether of that alcohol, in the solution of which proceeds the saponifying operation, and the polyvinylate of an alkali metal, since at the start there is noticeable a distinct odour of acetic ether; the acetic ether subsequently is saponified. Herrmann and Haehnel consider that the quantity of alkali may even be reduced. In such an event sodium acetate should act as a saponifying agent. These explanations of the saponification process are not clear. Such interpretation leads to the assumption of the formation of simple ethers or the acetic ether in the case of saponifying by sodium alcoholate. Besides this, it also necessitates the assigning to hydroxyls of polyvinyl alcohol a greater acid character than it is possible to admit in alcohol with such an aldol constitution. The fact of the formation during the saponification of the polyvinyl alcohol, which is distinguished by giving a persistent alkaline reaction (even after intensive washing with alcohol), testifies that there is being formed a rather stable alcoholate. In Staudinger's view the analysis of the saponified product yields far too small values for sodium.

As may be seen from the formula (I) of the polymerized vinyl acetate, the resultant polyvinyl alcohol should possess an aldol structure. In the opinion of Ruschinsky,[337] assuming the charges at the residual linkage of hydrocarbons, combined in vinyl acetate by the double bond to be of the opposite sign, it is this linkage which begins the connection of separate molecules into a continuous long chain :—

$$\text{I} \quad \ldots \overset{+}{\underset{|}{\text{CH}}} = \overset{-}{\text{CH}_2} \ldots \underset{\text{OCOCH}_3}{} \quad + \quad \ldots \overset{+}{\underset{|}{\text{CH}}} = \overset{-}{\text{CH}_2} \ldots \underset{\text{OCOCH}_3}{} \quad + \quad \ldots \overset{+}{\underset{|}{\text{CH}}} = \overset{-}{\text{CH}_2} \ldots \underset{\text{OCOCH}_3}{} \text{ etc.,}$$

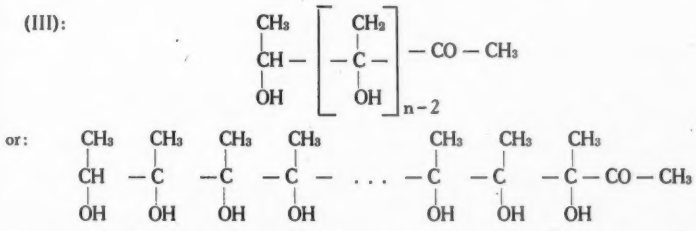
Assuming this to be the course of events, then it is evident that the formula (I) must have advantages over the formula (II) :—

$$\text{II} \quad \ldots \overset{+}{\underset{|}{\text{CH}}} = \overset{-}{\text{CH}_2} \ldots \underset{\text{OCOCH}_3}{} \quad + \quad \ldots \overset{-}{\text{CH}_2} = \overset{+}{\underset{|}{\text{CH}}} \ldots \underset{\text{CH}_3\text{COO}}{} \quad + \quad \ldots \overset{+}{\underset{|}{\text{CH}}} = \overset{-}{\text{CH}_2} \ldots \underset{\text{OCOCH}_3}{} \text{ etc.}$$



On the basis of certain theoretical considerations, Ruschinsky makes provision also for the above thermal polymerization of vinyl acetate.

By the saponification of such a polymer we obtain polyvinyl alcohol:—

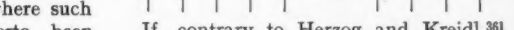


The formulæ of high molecular methyketose, possessing a genuine structure of hydrocarbons. This high molecular ketose would be the first homologue in the sphere of hydrocarbons, where such homologous series have hitherto been unknown.

This formula (III) of polymeric vinyl acetate and polyvinyl alcohol, supplementing the Staudinger formulæ (I) and (II), Ruschinsky has suggested as one of the possible expressions of the polymers derived from vinyl acetate and the polymerized vinyl alcohols obtained from them.

It should also be noted that, according to the work of Ostromislensky,[352] cauprene-bromide, in presence of aluminium chloride, reacts with benzene, with the rapid formation of polymers of styrene.

All the above-described polymers, irrespective of the actual mode of their polymerization course, are distinguished by the possession of one and the same characteristic grouping of a long substituted paraffin chain which possesses the following simple structure:—



If, contrary to Herzog and Kreidl,[361] we try to find the dependence not between the structure of a compound and its ability to resinify, but between the structure of the substance and its physical and practical properties of the resin, then this relationship for the group of resins given above may be formulated in the following manner: a combination with the properties of the resin should be built up from a substituted long paraffin chain.

However, not every compound with the similar chain should possess the resinous

properties, since the chemical nature of the substitutes and their number may vary within wide range the properties of a combination.

Adopting here the terminology of Witt, the paraffin chain should be designated as the resinogene grouping or resinogene, and substitutes—as the resinophore groups or resinophores. Only through introduction of resinophore groups there are developed the resin-forming properties of the paraffins.

The length of chain also plays a very substantial role in the properties of the resultant resin. From this point of view the resins are the derivatives of paraffins, and if, up to now, they were synthesized from the simple molecules, it was merely for the reason that the reaction passivity of paraffins did not allow heretofore their preparation from the latter. The butadiene rubber may be regarded as a partly dehydrogenated long (open or closed) paraffin chain. Then it follows that the aforesaid polymers, as well as rubbers, may be included into one and the same class of paraffin derivatives. Such a classification would introduce an order into accumulated but highly scattered facts of the chemistry of synthetic resins and would assist the strengthening of this new branch of applied science on a firm foundation.

(To be continued)

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(355) *Herrmann and Haehnel; Berichte*, 60, 1658. **(356)** *Staudinger, Frey and Stark; Ber.*, 60, 1782. **(357)** *Herrmann and Haehnel; Ber.*, 60, 1662. **(358)** *German Patent No.* 451,692; *French Patent No.* 624,754. **(359)** *Staudinger; Ber.*, 1782-88. **(360)** *Ostromislensky; "Cautchuck and Its Analogues,"* 3, 236, 1913. **(361)** *Herzog and Kreidl Zeit. Angew, Chem.* 67, 465, 1922.

WAR-BLINDED PRESS OPERATORS

(Continued from page 109)

J. Hancock has proved popular with the other moulders in the shop, who have done their best to help him and to make him feel at home, and the general effect of his presence in the department has been stimulating.

Whilst "J.H." was regarded by St. Dunstan's as representative of the type of man required as a plastic press operator, the future occupation of each man is very carefully considered, having regard to his wishes and suitability. St. Dunstan's are also going to install plastics moulding plant in their own workshops at Church Stretton, where preliminary instruction will be given. The wisdom of the choice will thus be proved during training at St. Dunstan's, and in consequence a prospective employer is assured that the trainee is likely to fulfil his requirements, particularly as St. Dunstan's make a point of getting into touch with the future employer during the early stages of the main training, thus enabling him to co-operate, if necessary, in ensuring that his particular requirements are incorporated during training.

In view of the expected passing of the Rehabilitation of Disabled Persons Bill in the near future, many employers may wish to visit the forthcoming "Back to Work" Exhibition at Burlington House, Piccadilly, from February 23 to March 14 inclusive, where a wide range of occupations by the disabled will be demonstrated and which, among other interesting exhibits by St. Dunstan's, will include the operation of a 50-ton plastics press, kindly loaned by Messrs. T. H. and J. Daniels, Ltd., of Stroud, Gloucester. The operator is to be "J.H."

It has previously been made known to members of the Federation that St. Dunstan's are anxious to add the names of firms willing to employ one or more of their trained moulders, as and when trained men become available in the future, to their industrial register. This will assist the placement of these men in the district best suited to their needs.

Communications should be addressed to Mr. Harry Bennett, Industrial Director, St. Dunstan's, 10, Park Crescent, London, W.1. Telephone number, Welbeck 7921.

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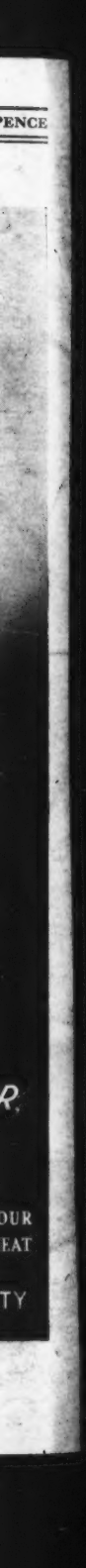
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